INDUCTIVE LOGIC

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PREFACE

THIS book originated in the class-room, where the author was teaching Dr. Fowler's *Elements of Inductive Logic*. Its ambition is to reproduce some of the excellences of that bright and interesting book, while substituting a sounder analysis of fundamental principles. The numerous extracts, introduced in the manner of Dr. Fowler, are designed both to elucidate the subject and to acquaint the student with the views and literary styles of a large variety of philosophical and scientific writers. Wherever anything has been found already well expressed, quotation has been preferred to restatement. The familiar manuals of inductive logic have been freely drawn upon, and their rich store of illustrations has been used without hesitation. Credit has generally been given; but sometimes it was impossible to make specific acknowledgment.

Mr. Mill is the greatest of all modern writers upon inductive logic, and upon his famous work all later authors have largely built. The school manuals are, for the most part, but outlines of his doctrine. But Mr. Mill's mind was a very peculiar one. It was impossible for one so acute not to see the truth, or for one so

candid not to state it. But these statements of truth are rather his *obiter dicta*, while his main contention is often some paradox. A "higher critic" might easily divide the *Logic* into two documents, by authors of opposing tendencies. An outline of Mill's system, like Dr. Fowler's, does him injustice; for it is just in what he thinks most important, that he is weakest. Freely acknowledging that most of what is true in this book has been learned from Mr. Mill, the author yet puts it forth with the hope that it will be found to contain a real, though small, contribution to the progress of science.

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CHAPTER I.

INTRODUCTORY.

INDUCTIVE Logic is the Science of the Discovery of Facts not directly observable. A few facts are known to us without discovery. Such are our personal identity, moral freedom, and obligation. Certain truths also are recognized by the mind as certain as soon as they are suggested. Evidence is not required to establish them, nor can it in any way confirm them. Of these are the axioms of Mathematics and the canons of Deductive Logic. This furniture is the same for all minds and the possession of it is what makes thinking possible. Only all minds do not with equal clearness analyze their own operations, and the most lack the patience, concentration, and strength to follow admitted principles to their ultimate consequences.

Whole sciences have been built up by simply developing the necessary implications of the few simple but universal truths intuitively perceived by every mind. Deductive Logic and Mathematics are examples. One peculiarity of them is that they are the same for all minds, and that when the terms used

are precisely understood there is no difference of opinion possible among sane men. These are pure sciences; they do not depend upon the actual existence of any person or thing, but we know that whatever does exist, necessarily conforms to them. If numbers or quantities of objects exist anywhere, they are in mathematical relations; if correct thinking upon any subject is done by rational beings anywhere, it is done according to the rules of deductive logic.

But the great bulk of our knowledge does not come to us by intuition. Beyond the few facts and truths with which the mind starts, lies the whole universe of reality, which we can know only through observation. Over against the pure sciences stand the applied sciences. The main value of the pure sciences is in the fact that they furnish the principles for constructing the applied sciences. The latter have no new formal principles of their own.

This last point is of supreme importance for the purpose now in hand. It has been extensively supposed that the field of thinking was divided into two kingdoms, ruled by two sovereigns, Deductive and Inductive Logic, under dissimilar constitutions, and that what was bad law in one kingdom might be good law in the other. It has been assumed that sometimes two thoughts which could show no right to union in the domain of Deduction could cross the border and, by a sort of Gretna Green marriage, make a synthesis in the kingdom of Induction. A little reflection should have shown all this to be a huge mistake. The canons of deductive logic are the universal laws of thought. They are invariably true, if ever true. The only

ground upon which we assent to any principle in deductive logic is our instant perception of its necessary and universal validity. If so, we cannot step into another province and escape its force. The limits of its domain are the same as those of correct thinking.

Deductive and Inductive Logic are not two sister sciences which divide the empire of thinking between them. They are not mutually exclusive ; one does not stop where the other begins. One is not the inverse of the other. One does not proceed from generals to particulars, while the other moves from particulars to generals. It is not true that one infers from the known to the known, while the other infers from the known to the unknown. It is not true that one is rigorously required to draw conclusions no wider than its premises, while the other is warranted in concluding the universal from a part. Many such assertions have been made by philosophers, but it is obvious without discussion that, if there is any truth in deductive logic, all these assertions are false ; for deductive logic sways a universal scepter or none. There can be no legitimate thinking except according to its laws. Inductive Logic is simply deductive logic regulating our reasoning upon our observations of the phenomena of the universe. It is deductive logic applied in the realm of reality. Whenever in our thinking a proposition is introduced the truth of which depends not upon its harmony with a previous admission, but directly upon observation, there our reasoning becomes Inductive. There is no new way of inferring peculiar to Induction. Deductive logic deals with the mutual harmony of propositions. Inductive logic deals with the harmony

between propositions and facts. No reasoning of any kind, deductive or inductive, can ever carry knowledge a step forward into the unknown, or do anything more than unfold what is contained in the premises.

We can learn the unknown only by observation ; we can reason upon our observations in no other way than deductively; for that is the only way men can reason at all. The rational action of the mind upon the data of observation is called Induction.

In defining Inductive Logic as the science of the Discovery of Facts we use the word *discovery* in the strictest sense, as meaning the ascertainment of the absolutely unknown.

To quote from Archbishop Whately:—

"There certainly *are* two kinds of 'New Truth' and of 'Discovery,' if we take those words in the widest sense in which they are ever used. First, such truths as were, before they were discovered, *absolutely* unknown, being not implied in anything we previously knew, though we might perhaps suspect them as probable; such are all *matters of fact* strictly so-called, when first made known to one who had not any such previous knowledge as would enable him to ascertain them *a priori*, *i.e.*, by reasoning; as, if we inform a man that we have a colony at Botany Bay; or that the earth is such a distance from the sun; or that platina is heavier than gold. The communication of this kind of knowledge is most usually and most strictly called *information;* we gain it from *observation*, and from *testimony;* no *mere internal workings* of our own minds (except when the mind itself is the very object to be observed), or *mere* discussions in words will make these known to us; though there is great room for sagacity *in judging what testimony to admit*, and forming *conjectures* that may *lead* to *profitable observation*, and to experiments with a view to it. The other class of Discoveries is of a very different nature. That which may be elicited by Reasoning,

and consequently is implied in that which we already know, we assent to on that ground, and not from observation or testimony: to take a geometrical truth upon trust, or to attempt to ascertain it by observation, would betray a total ignorance of the Science."[1]

In the following treatise we shall first inquire what is meant by "a fact," and shall then follow as exactly as possible the processes of mind by which facts are ascertained. The several fallacies to which the unwary are exposed will receive a large share of attention. The points to be considered will require hard thinking, but if any advance in clearness is made, the labor will be well repaid; for inductive thinking is the largest part of the work of life.

[1] Whately's *Logic*, p. 216.

CHAPTER II.

FACTS.

SINCE Inductive Logic is the science of the Discovery of Facts, it is necessary to consider at the outset what is meant by a fact. The human mind finds itself in a universe of phenomena. Through the senses it has perceptions of an external world, and through consciousness it knows its own modifications. Through these channels alone can the mind advance in knowledge of realities. Whatever has real existence is a fact. It may be a substance, an energy, a quality, an action, a state, or only some relation of substances, energies, qualities, actions, or states, but if it be perceived by the mind it is a fact. A dragon is not a fact, because it is not perceived; but the notion of a dragon is a fact, for that is an action of the mind of which I am conscious. The sun is a fact, the continent of America is a fact; the yellow color of gold, the attraction of a magnet, the likeness of two peas, are facts.

For the purposes of induction, facts may be classified as substantive facts and facts of relation. A substantive fact is a phenomenon considered apart, as independently existing. The yellowness of gold, the weight of gold, the malleability of gold, are substantive facts. A fact of relation connects in some way two substantive facts. That malleability and yellowness coexist in gold is a fact of relation.

Facts of relation are of three kinds: Facts of Resemblance, Facts of Coexistence, and Facts of Causation. Facts of Succession are often named among the ultimate kinds, but, as we shall see later, they are dependent upon simpler facts of causation.

One of the first lessons received by a child when it begins, as we say, to notice, is that there are many things in the world which resemble one another. Often the resemblance is so complete that the several phenomena seem but repetitions of the same thing. Thus from the observation of individual facts we pass through the perception of resemblances to the formation of a general concept. Common nouns are but the names of indefinite numbers of facts that resemble one another. The possibility of language arises from the constant repetition of similar things for which the same words will do.

It is also observed that there are certain more or less constant groups of substantive facts. We repeatedly find yellowness, sweetness, roundness, etc., coexisting; and to this assemblage of phenomena we give the name orange. We find yellowness, malleability, specific gravity 19.32, etc., coexisting, and we call this group of coexistences gold.

It is observed that when certain substantive facts or groups of substantive facts are in a certain collocation, a reaction occurs between them and that this is often attended by a change in one or more of the facts or groups. The relation between facts or groups of facts and their reactions, as well as the relation between any fact or group of facts and itself in a new form, is called Causation.

Further it is observed that certain substantive facts appear in succession; thus, after a ball is struck, we see it move; after a bell is swung, we hear a sound; after we touch fire, a smart follows. The relation by which an antecedent fact is linked to a consequent one we call Succession. Careful attention to the facts of succession is a large part of the work of science, since it is in most cases impossible to bring immediately into existence the phenomena which we desire; we produce them indirectly by producing their antecedents.

We do not know *why* certain simple facts coexist or *why* certain phenomena resemble each other or *why* certain things react as they do. These are ultimate facts of the Universe. There is no law of thought necessitating them; consequently they belong wholly to the domain of Induction. That the most refrangible rays of light have a violet color, and that the least refrangible rays have a red color, are facts for which no one expects ever to know a reason. Science makes no progress in this direction.

CHAPTER III.

OBSERVATION.

THE first step in the discovery of facts is always Observation. In order to know what is passing in our own minds or in the external world, we must give attention. Each act of attention is called an Observation. To quote the words of Bacon : "Man, being the servant and interpreter of Nature, can do and understand so much, and so much only, as he has observed in fact or in thought of the course of nature : beyond this he neither knows anything nor can do anything."[1] The five senses report to the mind the world of matter and force ; consciousness interprets to the thinking subject his own activities. Perception and consciousness supply the materials out of which the structure of Inductive Science is built up. But thought can build nothing without the use of those primary facts and necessary truths which are known by intuition without the process of discovery. There is nothing peculiar in any process of inference in inductive investigation ; for by the nature of the mind there can be but one mode of inference, namely that of deduction. The element of observation is the essential characteristic of Induction. Any syllogism is inductive in which one of the premises formulates the observation of some fact. The great work of Bacon was just this, that he with singular

[1] *Works*, vol. viii, p. 67.

clearness, persuasiveness, and charm of language called mankind to patient observation of Nature.

A distinction is sometimes made between Observation and Experiment. Dr. Fowler says: —

"To *observe* is to watch with attention phenomena as they occur; to *experiment* (or, to adopt more ordinary language, to *perform an experiment*) is not only to observe, but also to place the phenomena under peculiar circumstances, as a preliminary to observation. Thus every experiment implies an observation, but it also implies something more. In an experiment, I arrange or create the circumstances under which I wish to make my observation. Thus, if two bodies are falling to the ground, and I attend to the phenomenon, I am said to *observe* it, but if I place the bodies under the exhausted receiver of an air-pump, or cause them to be dropped under any special circumstances whatever, I may be said not only to make an observation, but also to perform an experiment. Bacon has not inaptly compared experiment with the torture of witnesses. Mr. Mill distinguishes between the two processes, by saying that in observation we *find* our instance in nature, in experiment we *make* it, by an artificial arrangement of circumstances."[1]

All this is very clear: indeed, it is so clear that one is surprised that the discussion of experiments did not come up in connection with a classification of *instances*, as natural and artificial. The fact that we can make instances artificially is of great importance in the progress of science; but it is not properly the basis of any distinction regarding the act of observation, which is always the same whatever the origin of the instance. There is no more contrast between an observation and an artificial instance than there is between an observation and a natural instance. Nor is the difference

[1] *Inductive Logic*, p. 40.

between natural and artificial instances, that is, between experiments and instances which are not experiments, always clearly traceable. All of the arrangements of human life and society are artificial; we learn from them to our cost, and often, in consequence, change our methods. Popular government is frequently spoken of as still an experiment; the construction of our armored battle ships is experimental. Yet instances of this kind are not arranged *for the sake* of learning from them, although *with the expectation* of learning, and improving.

The primary rule for any inductive thinking is to make sure of the observations. Starting with prejudices, guesses, or inferences, the truth never can be reached. Nothing but observation can establish a hitherto unknown fact. The explanation of the slow advance of science in ancient and mediæval times may be found mainly in the neglect of this simple rule. In spite of many errors in methods of thinking, the men of those times would have discovered a vast body of facts, if they had only given attention to them.

But the making of a precise and trustworthy observation is by no means the easy thing which at first it seems to be. Very much of what passes for observation is merely mistaken inference. An amusing illustration occurs in Charles Darwin's recollections of his father: —

"He himself never drank a drop of any alcoholic fluid. This remark reminds me of a case showing how a witness under the most favorable circumstances may be utterly mistaken. A gentleman-farmer was strongly urged by my father not to drink, and was encouraged by being told that he himself never touched

spirituous liquor. Whereupon the gentleman said, 'Come, come, Doctor, this won't do — though it is very kind of you to say so for my sake — for I know that you take a very large glass of hot gin and water every evening after your dinner.' So my father asked him how he knew this. The man answered, 'My cook was your kitchen-maid for two or three years, and she saw the butler every day prepare and take to you the gin and water.' The explanation was that my father had the odd habit of drinking hot water in a very tall and large glass after his dinner; and the butler used first to put some cold water in the glass, which the girl mistook for gin, and then filled it up with boiling water from the kitchen boiler."[1]

To quote from Dr. Fowler :—

"That which is strictly matter of perception does not admit of being called in question; it is the ultimate basis of all our reasoning, and, if we are to repose any confidence whatever in the exercise of our faculties, must be taken for granted. But there are few of our perceptions, even of those which to the unphilosophical observer appear to be the simplest, which are not inextricably blended with inference. Thus, as is well known to every student of psychology, in what are familiarly called the perceptions of distance and of form, the only perception proper is that of the various tints of color acting on the retina of the eye, and it is by a combination of this with perceptions of touch, and the muscular sense, that the mind gains its power of determining form and distance. Now, a judgment of this kind, which is really due to inference, is, especially by the uneducated and unreflecting, perpetually mistaken for that which is due to direct observation: and thus what is really only an inference from facts is often emphatically asserted to be itself a matter of fact."[2]

To quote from Mr. Mill :—

"One of the most celebrated examples of a universal error produced by mistaking an inference for the direct evidence of the senses, was the resistance made, on the ground of common sense,

[1] *Life and Letters*, p. 15. [2] *Inductive Logic*, p. 273.

to the Copernican system. People fancied that they saw the sun rise and set, the stars revolve in circles round the pole. We know that they saw no such thing; what they really saw was a set of appearances, equally reconcilable with the theory they held and with a totally different one. It seems strange that such an instance as this of the testimony of the senses pleaded with the most entire conviction in favor of something which was a mere inference of the judgment, and, as it turned out, a false inference, should not have opened the eyes of the bigots of common sense, and inspired them with a more modest distrust of the competency of mere ignorance to judge the conclusions of cultivated thought.

"In proportion to any person's deficiency of knowledge and mental cultivation is, generally, his inability to discriminate between his inferences and the perceptions on which they were grounded. Many a marvelous tale, many a scandalous anecdote, owes its origin to this incapacity. The narrator relates, not what he saw or heard, but the impression which he derived from what he saw or heard, and of which perhaps the greater part consisted of inference, though the whole is related not as inference but as matter of fact. The difficulty of inducing witnesses to restrain within any moderate limits the intermixture of their inferences with the narrative of their perceptions, is well known to experienced cross-examiners; and still more is this the case when ignorant persons attempt to describe any natural phenomenon. 'The simplest narrative,' says Dugald Stewart, 'of the most illiterate observer involves more or less of hypothesis; nay, in general, it will be found that, in proportion to his ignorance, the greater is the number of conjectural principles involved in his statements. A village apothecary (and, if possible, in a still greater degree, an experienced nurse) is seldom able to describe the plainest case, without employing a phraseology of which every word is a theory: whereas a simple and genuine specification of the phenomena which mark a particular disease, a specification unsophisticated by fancy, or by preconceived opinions, may be regarded as unequivocal evidence of a mind trained by long and successful study to the most difficult of all arts, that of the faithful *interpretation* of nature.'" [1]

[1] *Logic*, p. 545.

CHAPTER IV.

PRIMARY INDUCTIONS.

AN Induction is a generalization, or an inference, based upon propositions that state observed facts. The truth inferred may be general or particular, but it must be one which we cannot perceive in a single act of observation. When we know the existence of anything by simply attending to it, we do not say that we know it inductively : we know it directly. The word Induction is applied both to the proposition enunciated and to the process of mind by which that proposition is reached. That "all men are mortal," I know by induction, and the truth is itself an induction.

Inductions are based either wholly upon observations, in which case we call them Pure Inductions ; or they are based partly upon observation and partly upon intuitively known truth, in which case we call them Mixed Inductions. Pure inductions are either Complete or Incomplete, according as we have or have not observed all the facts included in the statement. They are either Primary or Secondary, according as they are made directly by generalizing a number of observations, or indirectly by combining syllogistically a single new observation with a previous induction. These distinctions will become clear as we advance. The present chapter deals with Primary Inductions.

It soon becomes plain to every child, when he begins to observe the world, that there is an existing order of

things. It is perfectly easy to conceive of a world in which every object should be unique and every event a surprising novelty. Such a world would contradict no necessity of thought, although it would be hopelessly bewildering. But such is not our world. The child's earliest impression is of a certain permanence and uniformity in its environment. The same objects and experiences remain or recur.

This conviction of an existing order finds expression in language. The present tense in grammar does not denote a mere moment separating the past and the future ; it denotes a considerable and indefinite expanse of time. Such a proverb as "The burnt child shuns the fire" is stated in the present tense, as formulating a fact of the existing order.

That experience falls largely into lines of uniformity is early perceived. The child learns that there are things called apples which are round and red and good to eat, and that there are things called cats which have soft fur and long tails and sharp claws, and that these things are liable to scratch. The profoundest question in the whole science of inductive logic is : How are these generalizations reached? How can we ever discover that we are upon the line of a uniformity? But this is really only a sort of metaphysical puzzle, like the question of the possibility of motion. The existence of lines of uniformity is every moment forced upon our observation, and the fact that they do extend is equally conspicuous.

A Primary Induction is the statement of an observed uniformity. Do we reach it by any process of inference? Philosophers have thought so. There is thought

to be here a new and peculiar kind of inference of which deductive logic knows nothing. Professor Davis says: "Induction is an immediate synthetic inference generalizing from and beyond experience."[1] But this does not appear to be a correct analysis. When there is an inference we necessarily look about for propositions which can be syllogistically combined. Professor Davis claims that we intuitively know the Uniformity of Nature, and he unconsciously makes this his major premise. But the uniformity of nature can be known and defined only inductively, not intuitively. It is a discovery of induction, not the basis of it.

No: if there is a permanent or recurring fact in nature, we ascertain it simply by generalization, not by inference.

How do we know that the mill is standing by the river? We cannot be looking at it all of the time. Having seen it a hundred or a thousand times we have come to believe in its permanence. How do we know that the water is flowing over the mill-dam? We have seen it often and have come to think it continuous. Here is a permanent fact — the mill, and a uniformity — the flow of the water; how do we come to feel assured of them? Not by any process of inference, but simply by generalization. We have not reasoned about the future or the unknown, but about the present and the known. Whether the world will come to an end to-night, and the river and the mill be annihilated, we cannot predict from our observations upon them; all that we know is that this permanence — the mill, and this uniformity — the flow of the stream, are facts of

[1] *Inductive Logic*, p. 6.

the existing order ; and since it would be irrational to act, without evidence, upon the supposition of the cessation of the existing order, we keep on carrying grist to the mill.

A primary induction does not rest upon a process of inference any more than does our belief in any permanent fact. That the cliffs of England are white is a permanent fact ; that the crows of England are black is a uniformity. We cannot be looking at the cliffs all the time, and we cannot examine all the crows ; but having looked at the cliffs frequently, and having seen a large number of crows, we rest in the assurance that we know the existing order. Should we wake up some morning and find the cliffs blackened, we should simply recognize that the order had changed. Should we find in visiting a remote part of the kingdom a flock of white crows, we should simply observe that we had passed beyond the former area of observation. If our expectation of finding the cliffs white and the crows black at the next observation rested upon any logical necessity, our not finding them so would require a doubt of our own sanity.

The suggestion has been made that we base our belief in the truth of a primary induction upon our faith in the veracity of God. But surely such an induction as that "the Cretans are always liars" cannot be based upon the veracity of God ; it rests merely upon observation of the uniform mendacity of those depraved people.

The sort of induction we are now describing has been known, since Bacon's time, as *Inductio per Enumerationem Simplicem*, Induction by Simple Count. "It

consists in ascribing the character of general truths to all propositions which are true in every instance that we happen to know of." Mr. Mill's attitude toward such inductions in the first edition of his *Logic* was curious. Although holding that the uniformity of Nature, the law of Causation, and the axioms of Mathematics are established only in this way, he yet inclined to deny to the process even the name of induction. He said: "This is the kind of induction, if it deserves the name, which is natural to the mind when unaccustomed to scientific methods." Later Mr. Mill omitted the clause "if it deserves the name"; but his disparaging tone continued and infected logical writers. Thus, Dr. Fowler says:—

"But not only is the *Inductio per Enumerationem Simplicem* the mode of generalization natural to immature and uninstructed minds; it is the method which, till the time of Bacon, or at least till the era of those great discoveries which shortly preceded the time of Bacon, was almost universal." "When men first begin to argue from their experience of the past to their expectation of the future, or from the observation of what immediately surrounds them to the properties of distant objects, they seem naturally to fall into this unscientific and unreflective mode of reasoning."[1]

Bacon himself seems responsible for this sneer; he says:—

"Inductio quae procedit per enumerationem simplicem, res puerilis est, et precario concludit, et periculo exponitur ab instantia contradictoria, et plerumque secundum pauciora quam par est, et his tantum modo quae praesto sunt pronunciat."[2]

Still there remains an inconsistency in Mr. Mill's doctrine; for he says most justly:—

[1] *Inductive Logic*, pp. 280, 281. [2] *Novum Organum*, lib. 1, aph. cv.

"Experience must be consulted in order to learn from it under what circumstances arguments from it will be valid. We have no ulterior test to which we subject experience in general; but we make experience its own test. Experience testifies, that among the uniformities which it exhibits or seems to exhibit, some are more to be relied on than others; and uniformity, therefore, may be presumed from any given number of instances, with a greater degree of assurance, in proportion as the case belongs to a class in which the uniformities have hitherto been found more uniform. This mode of correcting one generalization by another, a narrower generalization by a wider, which common sense suggests and adopts in practice, is the real type of scientific induction."[1]

The truth could not be better set forth than in the foregoing accurate and discriminating statement; after all, the "real type of scientific induction" is merely an *inductio per enumerationem simplicem*, carefully made.

Experience gives us not only uniformities, but uniformities among uniformities. Not only does this ox uniformly chew the cud, but all oxen uniformly chew the cud, and all other sorts of animals with similar structure uniformly chew the cud. Not only does this piece of lead maintain a uniform specific gravity of 11.4, but there is a uniformity in specific gravity among all pieces of lead, and, moreover, every different substance maintains a uniform specific gravity. What we call the "Principle of the Uniformity of Nature" is merely the wide primary induction that the various limited uniformities of nature persist. There is no other sense in which nature is uniform. It is not meant, of course, that every object is like every other object, and every event like every other event.

[1] *Logic*, p. 232.

"Every person's consciousness assures him that he does not always expect uniformity in the course of events; he does not always believe that the unknown will be similar to the known, that the future will resemble the past. Nobody believes that the succession of rain and fine weather will be the same in every future year as in the present. Nobody expects to have the same dreams repeated every night. On the contrary everybody mentions it as something extraordinary, if the course of nature is constant, and resembles itself in these particulars. To look for constancy where constancy is not to be expected, as for instance that a day which has once brought good fortune will always be a fortunate day, is justly accounted superstition."[1]

The assurance with which a primary induction is held, depends upon the number of instances from which it is generalized. If the number is small, the assurance is imperfect: if the number of instances is practically infinite, the assurance is practically complete. Belief shades thus from faint presumption, by imperceptible increments, into positiveness. When at last we have examined all the instances, the induction is complete and we know. To quote Mr. Mill:—

"Induction by simple enumeration — in other words, generalization of an observed fact from the mere absence of any known instance to the contrary — affords in general a precarious and unsafe ground of assurance; for such generalizations are incessantly discovered, on further experience, to be false. Still, however, it affords some assurance, sufficient, in many cases, for the ordinary guidance of conduct. It would be absurd to say, that the generalizations arrived at by mankind in the outset of their experience, such as these — food nourishes, fire burns, water drowns, — were unworthy of reliance. There is a scale of trustworthiness in the results of the original unscientific induction; and on this diversity (as observed in the fourth chapter of the present

[1] Mill's *Logic*, p. 226.

book) depend the rules for the improvement of the process. The improvement consists in correcting one of these inartificial generalizations by means of another. As has been already pointed out, this is all that art can do. To test a generalization, by showing that it follows from or conflicts with some stronger induction, some generalization resting on a broader foundation of experience, is the beginning and end of the logic of induction." [1]

Quite a different view from the foregoing has, however, been often taken. The name induction has been denied to the generalization of experience, and has been reserved exclusively for statements in regard to the unobserved. Professor Bain speaks as follows: —

"Induction is the arriving at General Propositions, by means of Observation or Fact.

"In an induction there are three essentials: (1) the result must be a *proposition* — an affirmation of concurrence or non-concurrence — as opposed to a Notion; (2) the Proposition must be *general*, or applicable to all cases of a given kind; (3) the method must be an appeal to *observation* of fact.

"The Propositions established by induction are *general*. A single individual concurrence, as 'the wind is shaking the tree,' is in its statement a proposition, but not an induction. On such individual statements we base inductions, but one is not enough. If the coincidence recurs, we mark the recurrence; we are affected by the shock or flash of identity, a very important step in our knowledge. If, pursuing the suggestion, we remark that as often as the wind is high, the trees are shaken; that the two things have concurred within the whole course of our observation; that the same concurrence has been uniform in the observation of all other persons whose experience we have been informed of, — we are then entitled to make a still wider sweep, and to say, 'every time that a high wind has been observed, a waving of the trees has also been observed.'

"Still, with all this multitude and uniformity of observations,

[1] *Logic*, p. 401.

there is no proper Induction. What then remains? The answer is, the extension of the concurrence from the observed to the unobserved cases — to the *future* which has not yet come within observation, to the *past* before observation began, to the *remote* where there has been no access to observe. This is the leap, the hazard of Induction, which is necessary to complete the process. Without this leap our facts are barren; they teach us what has been, after the event; whereas we want knowledge that shall instruct us before the event, that shall impart what we have no means of observing. A complete induction, then, is a generalization that shall express what is conjoined everywhere, and at all times, superseding forever the labor of fresh observation.

"We thus contrast Induction with that species of 'Induction improperly so-called,' where a general statement merely sums up the observed particulars.

"If, after observing that each one of the planets shines by the sun's light, we affirm that 'all the planets shine by the sun's light,' we make a general proposition to appearance, but it falls short of an induction in the full sense of the term. The general statement is merely another way of expressing the particulars; it does not advance beyond them. But without such advance there is no real inference, no march of information, no addition to our knowledge. Induction is the instrument of multiplying and extending knowledge; it teaches us how, from a few facts observed, to affirm a great many that have not been observed. If, from the observation of the planets now discovered, we make an assertion respecting all that have yet to be discovered, we make the leap implied in real or inductive inference. If the assertion had been made when only six planets were known, actual observation would have been the guarantee for those six, induction for the remaining hundred or upwards.

"The sole method of attaining Inductive truths being the observation and comparison of particulars, the sole evidence for such truths is Universal Agreement.

"A permanent or uniform concurrence can be established, in the last resort, only by the observation of its uniformity. That unsupported bodies fall to the ground, is a conjunction suggested by the observation of mankind, and proved by the unanimity of all

observers in all times and places. What is found true, wherever we have been able to carry our observations, is to be accepted as universally true, until exceptions are discovered.

"Through this method alone — of Universal Agreement in detail — can our most general and fundamental truths be discovered and proved. It is the *only proper inductive method*."[1]

This account of induction cannot be consistently accepted. The Professor suggests no criterion by which one may know when he is justified in taking the hazard of a leap in the dark and making an induction. He does not say how many instances must be observed before the leap is warranted. If only that part of a generalization which refers to the unobserved is "induction proper," and if "the only proper inductive method is the observation of particulars," and if "the sole evidence for such truths is universal agreement," — it is impossible to see how we can have any induction at all. If "a permanent or uniform concurrence can be established in the last resort, only by the observation of its uniformity," then it cannot be established by what Professor Bain calls induction; for "proper induction" deals only with the unobserved. The puzzle here is simply what grows out of the mind's necessary assumption of the continuity of the existing order. Of course no one can prove the permanence of a thing by observing it every moment. How do I know that the sun does not go out of existence whenever I cease to look at it? The answer is, that having no reason in experience to think that the existing order depends upon my attention, I must assume that it does not. The truth is that if, after observing

[1] *Logic: Deductive and Inductive*, pp. 231, 232, 237.

that each of the planets shines by the sun's light, we affirm that "all the planets shine by the sun's light," we take the "hazard" of the continuance of the existing order, for we are not at this moment observing them.

When we say, Salt preserves meat, we are not, according to Professor Bain, uttering an induction; because the preserved meat is now under our eyes; it is only when we say that salt will preserve meat, or that salt has preserved meat (referring strictly to the *unobserved* cases in the past), that an induction is made: yet this can be established only by "the unanimity of all observers," which it is manifestly impossible to ascertain, and if it could be ascertained, the assertion would at once cease to be an induction (since no longer referring to the unobserved and making no addition to knowledge): it would be a mere generalization, an "induction improperly so-called."

It would be impossible to make a catalogue of all of the primary inductions held by the mind of a single person. They refer to every object and undergo constant revision and extension. They are not always, nor even usually, in the form of universal truths. That three-fifths of the wheat in the state is bad, and that on the average ten men in a thousand of a certain class die every year, are primary inductions. By combination of inductions of small extent, wider ones are made, and a steady advance in generality is the result. It is the peculiar glory of modern science to have formulated such grand inductions as the law of Inertia, that is, that every body continues in its state of rest or motion unless acted upon; the law of the persistence of energy; the law of the persistence of matter; the law

that the will can transform some of the energy of the body. These laws generalized into a higher induction give us the great law of Causation; namely, that if any change occurs in things, the matter, the force, and the will concerned, can be found among previously existing things. Another generalization is, that as far as man can explore, the same order is found existing. So far as the sun and stars can be observed, they conform to the one existing order.

How long the existing order will continue, we cannot, in any proper sense, be said to know. Reasoning cannot make any addition to knowledge. Up to the year 79 A.D., the volcano of Vesuvius had had, within the memory of man, no eruption. Experience seemed to have demonstrated that it was safe to live upon its slopes; but the eruption came and proved the contrary. Manifestly, those uniformities which depend upon the co-operation of a number of causes are less stable than those which are simpler. Nothing is simpler than the law of gravitation; hence such a uniformity as the rising and setting of the sun is relied upon with vastly more faith than is the quiescence of a volcano. But that is only a matter of degree.

Mr. Mill has made a distinction between Empirical Laws and Ultimate Laws. "An empirical law is an observed uniformity, presumed to be resolvable into simpler laws, but not yet resolved into them." The distinction is simple enough in thought, but in practice it is impossible to draw the line.

It may be well, in closing this chapter, to say a few words upon the curious popular misunderstanding of the maxim that "The exception proves the rule."

When one has laid down with positiveness some supposed general principle, and his attention is called to a fact inconsistent with it, it is not uncommon to hear him say, rather triumphantly, "Oh, that is simply the exception that proves the rule"; and he seems somehow to feel better fortified in his position than before, his generalization being now provided with a necessary equipment. Even respectable writers fall into this absurd mode of speaking. The fallacy consists in taking as a principle, valid in the world of facts, what has no sense at all except in the world of statements. It is taken as if the finding of a black sheep were in some way a confirmation of the generalization that all sheep are white; although, of course, every such case is just so much disproof. But if some person, a lawmaker, an expert, or an authority of some sort, in making statements, excepts a person or thing, then it may be legitimately inferred that he assumes the rule to be the other way. If, for example, one who lives on the shore of Lake Erie speaks of a fine day in March with surprise, his so speaking is equivalent to testimony that bad weather then and there is the rule; but a chance visitor, luckily enjoying bright skies, would not on that account more readily assent to the assertion that March weather on Lake Erie is generally bad. Those who in their youth have been compelled to learn the rules for Latin quantity, find it most convenient to remember them by the exceptions. Knowing that *amīcus* is given as one of the exceptions in its class, I have no difficulty in recalling the rule that "Words in *-icus* shorten the penult"; but this proves only the statement of the grammarian, nothing more. In short, the word *excep-*

tion has two senses ; first, it means the act of excepting ; secondly, the thing excluded ; the popular fallacy consists in substituting the second for the first sense, and in supposing that the discovery of a few words with long *i* before the termination *-cus* makes it easier to believe that *i* so situated is generally short ; when in truth the proof is wholly in the fact that a competent authority has declared these words to be exceptions.

CHAPTER V.

SECONDARY INDUCTIONS.

HAVING by the slow, and often tedious, process of observing many particulars, established our primary inductions, we are prepared to advance with ease and rapidity in the making of Secondary Inductions. A primary induction, we have learned, is a generalization of experience, a truth established by repeated observations. A Secondary Induction is the conclusion of a syllogism of which one premise is a primary induction, and the other premise is the statement of an observed fact. When, for example, it has once been admitted, as a primary induction, that specific gravities are constant, a single experiment upon a newly discovered metal is sufficient to establish its specific gravity to the satisfaction of the scientific world. The single observation is combined deductively with the primary induction, thus:—

All specific gravities are constant;
The specific gravity of this piece of Rubidium is 1.5;
Therefore, the specific gravity of Rubidium is always 1.5.

This illustration shows in an interesting manner how induction and deduction are combined. There is discovery here, but it is not reached by anything peculiar in the method of inference; that is simply deductive. But each of the premises records a discovery made by observation; hence the syllogism is inductive. It has

been objected to such syllogisms, that the universal proposition could not be affirmed unless we already knew the conclusion, and that consequently there is only an apparent, and not a real advance in knowledge. The reply is, that no reasoning can ever make a substantial advance in knowledge; to give knowledge is the function of intuition and observation alone. Reasoning can only display explicitly what was already involved implicitly. There is, however, in this case what comes very near to positive discovery. It has appeared in the last chapter that practical certainty is reached, regarding many of the uniformities of nature, long before all instances have been examined; indeed, from the very character of most uniformities, it is impossible that all instances should be examined. We become satisfied that all men are mortal, upon knowledge of what is a very limited part of the experience of the race. When, therefore, it is observed that Socrates is a man, the conclusion that he is mortal comes very near to being a discovery. The fact that Socrates is a man is a discovery of observation; Socrates might be the name of a dog or of a ship. This premise brings into the syllogism an advance in knowledge.

In every-day thinking, primary and secondary inductions are constantly mingled, and almost all of our generalizations partake of the nature of both, or are proved in both ways. There is, for instance, a perpetually accumulating mass of experience that lead is heavy, that aluminum is light, and so on. Independently of anything else, a primary induction can be made regarding each one of the metals. But at the same time the broader primary induction that specific

gravities are constant is receiving perpetual confirmation, so that each single experience with lead or aluminum abundantly warrants a secondary induction covering the whole existing amount of that metal.

After observing a thousand uniformities, every one perceives that objects and events in this world run in lines of similarity; a strong presumption, therefore, arises that any given object is only one of a class. Finding several similar things, we combine the observation with the previously established generalization that several similarities indicate the line of a uniformity, and make an induction accordingly. This is what Dr. Fowler has called "the mode of generalization natural to immature and uninstructed minds"; but in truth it is the necessary procedure of all sane minds. The immaturity and inexperience appear in neglecting care in determining the exact course and limits of the lines of uniformity.

Archbishop Whately regarded the uniformity of the course of nature as the ultimate major premise in *all* inductions. That is, he did not provide for any primary inductions at all. But the uniformity of nature is too vast and indefinite an induction for immediate use, even in most cases of secondary induction. The doctrine does not mean that all objects are alike, and all events alike; it only means that all particular lines of uniformity persist. What these lines are, must be determined simply by accumulating instances and making generalizations. We must have observed a number of lines of particular uniformity, before we could ascend to the induction of the general uniformity of nature. To quote Mr. Mill:—

"But though it is a condition of the validity of every induction that there be uniformity in the course of nature, it is not a necessary condition that the uniformity should pervade all nature. It is enough that it pervades the particular class of phenomena to which the induction relates. An induction concerning the motions of the planets, or the properties of the magnet, would not be vitiated though we were to suppose that wind and weather are the sport of chance, provided it be assumed that astronomical and magnetic phenomena are under the dominion of general laws. Otherwise the early experience of mankind would have rested on a very weak foundation; for in the infancy of science it could not be known that all phenomena are regular in their course."[1]

The strangest fact in the history of inductive science is that writers have never distinctly recognized and stated the fundamental differences of the three great classes of inductions, but have persisted in attempting to make one comprehensive definition for all, as if the process of induction were always precisely the same thing. Thus Whately provides only for secondary inductions; Bain, only for primary ones; Minto and Davis, only for such secondary ones as fall under the primary induction of causation, which is but a fraction of the field of experience. Mr. Mill has thrown so much light upon the whole subject, and has made so many just discriminations, that it is all the more surprising that he has not gone a step farther. He says:—

"Whatever be the most proper mode of expressing it, the proposition that the course of nature is uniform, is the fundamental principle, or general axiom of Induction. It would yet be a great error to offer this large generalization as any explanation of the inductive process. On the contrary, I hold it to be itself an instance of induction, and induction by no means of the most obvious kind. Far from being the first induction we make, it is

one of the last, or at all events one of those which are latest in attaining strict philosophical accuracy. As a general maxim, indeed, it has scarcely entered into the minds of any but philosophers; nor even by them, as we shall have many opportunities of remarking, have its extent and limits been always very justly conceived. The truth is, that this great generalization is itself founded on prior generalizations. The obscurer laws of nature were discovered by means of it, but the more obvious ones must have been understood and assented to as general truths before it was ever heard of. We should never have thought of affirming that all phenomena take place according to general laws, if we had not first arrived, in the case of a multitude of phenomena, at some knowledge of the laws themselves; which could be done no otherwise than by induction. In what sense, then, can a principle, which is so far from being our earliest induction, be regarded as our warrant for all the others? In the only sense in which (as we have already seen) the general propositions which we place at the head of our reasonings when we throw them into syllogisms, ever really contribute to their validity. As Archbishop Whately remarks, every induction is a syllogism with the major premise suppressed; or (as I prefer expressing it) every induction may be thrown into the form of a syllogism by supplying a major premise. If this be actually done, the principle which we are now considering, that of the uniformity of the course of nature, will appear as the ultimate major premise of all inductions, and will, therefore, stand to all inductions in the relation in which, as has been shown at so much length, the major proposition of a syllogism always stands to the conclusion; not contributing at all to prove it, but being a necessary condition of its being proved; since no conclusion is proven, for which there cannot be found a true major premise."[1]

In this passage the characteristic peculiarities of Mr. Mill's mind appear; he tells the truth most clearly, but at the same time contradicts and obscures it. If the uniformity of nature is a discovery of induction it cannot

[1] *Logic*, p. 224.

be the fundamental principle of induction. We cannot lift ourselves over the fence by our own boot-straps. Primary inductions are but generalizations and need no major premise; for they cannot be thrown into syllogistic form. Secondary inductions have for their major premises the particular uniformities which are proximate. We cannot take the uniformity of nature as a major premise, and making a single observation, proceed at once to a secondary induction, reasoning, This object is mortal; But since nature is uniform; All objects are mortal. The uniformity of nature is a generalization only regarding uniformities; to use it at all we must, by accumulating particulars, ascertain the existence of a uniformity. And then we can reason, All uniformities persist; This is a uniformity; Therefore it will persist. The only inference that can be drawn from the uniformity of nature is the persistence of a newly discovered uniformity.

Professor Minto says:—

"In his antagonism to a supposed doctrine that all reasoning is from general to particular, Mill maintained *simpliciter* that all reasoning is from particulars to particulars. Now, this is true only *secundum quid*, and although, in the course of his argument, Mill introduced the necessary qualifications, the unqualified thesis was confusing. It is perfectly true that we may infer — we can hardly be said to reason — from observed particulars to unobserved. We may infer, and infer correctly, from a single case. The village matron, called in to prescribe for a neighbor's sick child, infers that what cured her own child will cure the neighbor's, and prescribes accordingly. And she may be right. But it is also true that she may be wrong, and that no fallacy is more common than reasoning from particulars to particulars without the requisite precautions." [1]

We cannot admit that there is any such thing as inferring, or reasoning, from one particular to another. The village matron does not infer from her child to the neighbor's *grindstone* or *barn-door*, and the fact that she does not is proof that she does not take particulars at random. Her process of thought is this: These two particulars (the children) belong to the same natural kind; Things of the same natural kind are similarly affected by the same thing; This medicine cured my child; Therefore, it will cure this one. The matron's reasoning is syllogistic throughout; if she makes an error it is simply in observation as to whether the medicine did cure her own child, or as to whether the neighbor's child is in the same physical condition. The matron proceeds from primary inductions through particular observations to secondary inductions. The "requisite precautions" always include attention to these steps.

In the first edition of his *Logic*, Mr. Mill said:—

"The induction by which they [the mathematical axioms and the law of causation] are established is of that kind which can establish nothing but empirical laws; an empirical law, however, of which the truth is exemplified at every moment of time and in every variety of place or circumstance, has an evidence which surpasses that of the most rigid induction, even if the foundation of scientific induction were not itself laid (as we have seen that it is) in a generalization of this very description."[1]

In this remarkable passage, it was assumed that only secondary inductions are scientific inductions, and yet it was affirmed that they are based upon the primary,

[1] Page 340.

and that the primary are so firm that they would surpass the secondary, were it not that the secondary, being based upon them, must be exactly as strong. It is true that in the eighth, the last, edition of the *Logic* this passage is omitted; but the confusion of thought still attaches to Mr. Mill's doctrine, and appears in the books which, like Dr. Fowler's, are based upon his earlier editions. Mr. Mill's contention amounts simply to this, that a secondary induction made from one clear case in combination with one of our broadest primary inductions (say the law of causation), is far more trustworthy than a new primary induction made independently regarding a limited class of phenomena. And this is undoubtedly true.

CHAPTER VI.

MIXED INDUCTIONS.

We know by intuition that if certain things are true, certain other things are also true. When, therefore, one of these facts of the first class has been established by observation, one of the facts of the second class can be established by making a syllogism, of which one premise is known to be true by intuition, and the other by observation; the conclusion will be a *Mixed Induction.*

We know, mathematically, that if the surface of the sea is not flat, but curved, the masts of ships must appear before their hulls. We observe that the masts do actually appear first. The conclusion, that the surface of the sea is curved, is a mixed induction.

The nature of mixed inductions is well illustrated in the famous discoveries of Sir Isaac Newton. We quote from Mr. Mill:—

"Newton began by an assumption, that the force which at each instant deflects a planet from its rectilineal course, and makes it describe a curve round the sun, is a force tending directly towards the sun. He then proved that, if it be so, the planet will describe, as we know by Kepler's first law it does describe, equal areas in equal times; and, lastly, he proved that if the force acted in any other direction whatever, the planet would not describe equal areas in equal times. It being thus shown that no other hypothesis could accord with the facts, the assumption was proved; the hypothesis became a law, established by the method of difference. Not only did Newton ascertain by this hypothetical process the

direction of the deflecting force; he proceeded in exactly the same manner to ascertain the law of variation of the quantity of that force. He assumed that the force varied inversely as the square of the distance; showed that from this assumption the remaining two of Kepler's laws might be deduced; and, finally, that any other law of variation would give results inconsistent with those laws, and inconsistent, therefore, with the real motions of the planets, of which Kepler's laws were known to be a correct expression."[1]

That is, Newton showed mathematically that if the planets move in a given manner, they must be affected by a force acting toward the sun and varying inversely as the square of the distance; Kepler had shown that the planets *do* move in the given manner; the mixed induction was therefore established that *there is such a force.*

It will be seen that Mr. Mill introduces this as an example of hypothesis, but it will also be seen that it was wholly unnecessary for Newton to make any conjecture or assumption. All he had to do was to ask, The motions being as they are observed to be, what, mathematically, must be the direction and law of the force? It is not necessary to form an hypothesis that the surface of the sea is curved and then test that hypothesis by looking at an incoming ship. All that is necessary is to state the mathematical possibilities and then observe the facts; the conclusion follows of course.

We take another fine illustration from Sir John Herschel: —

"It had been objected to the doctrine of Copernicus, that, were it true, Venus (and, it might have been added, Mercury, as the other inferior planet) should appear sometimes horned like the

moon. To this he answered by admitting the conclusion, and averring that, should we ever be able to see its actual shape, it would appear so. It is easy to imagine with what force the application would strike every mind when the telescope confirmed this prediction, and showed the planet just as both the philosopher and his objectors had agreed it ought to appear." [1]

Having considered the three kinds of induction, we are now ready to answer several questions proposed by Mr. Mill:—

"In order to a better understanding of the problem which the logician must solve if he would establish a scientific theory of induction, let us compare a few cases of incorrect inductions with others which are acknowledged to be legitimate. Some, we know, which were believed for centuries to be correct, were, nevertheless, incorrect. That all swans are white, cannot have been a good induction, since the conclusion has turned out to be erroneous. The experience, however, on which the conclusion rested was genuine. From the earliest records, the testimony of all the inhabitants of the known world was unanimous on the point. The uniform experience of the inhabitants of the known world, agreeing in a common result, is not always sufficient to establish a general conclusion. . . . When a chemist announces the existence and properties of a newly discovered substance, if we confide in his accuracy, we feel assured that the conclusions he has arrived at will hold universally, although the induction be founded but on a single instance. We do not withhold our assent, waiting for a repetition of the experiment; or if we do, it is from a doubt whether the one experiment was properly made, not whether, if properly made, it would be conclusive. Here, then, is a general law of nature, inferred without hesitation from a single instance; an universal *proposition from a singular one*. Now, mark another case and contrast it with this. Not all the instances which have been observed since the beginning of the world, in support of the general proposition that all crows are black, would be deemed a sufficient presumption of the truth of the proposition, to outweigh

[1] *Discourse on the Study of Natural Philosophy*, § 299.

the testimony of one unexceptionable witness who should affirm that in some region of the earth not fully explored, he had caught and examined a crow, and had found it to be gray.

"Why is a single instance, in some cases, sufficient for a complete induction, while in others, myriads of concurring instances, without a single exception known or presumed, go such a very little way towards establishing an universal proposition? Whoever can answer this question knows more of the philosophy of logic than the wisest of the ancients, and has solved the great problem of induction." [1]

Our discussion up to this point has prepared the student to answer Mr. Mill's question, and to claim the proud distinction of "knowing more of the philosophy of logic than the wisest of the ancients." It is plain that when a chemist determines for the first time the specific gravity of a new substance, rubidium, for example, he combines this one observation deductively with the acknowledged primary induction that chemical and physical properties of the several natural kinds are constant, and thus reaches at once the secondary induction, that the specific gravity of rubidium will be always found 1.5, or whatever the determination may be. Whenever a single instance leads to an induction, it is a secondary induction or a mixed induction. Bacon called such instances "crucial instances," from the Latin *crux*, a finger-post; since they point out the line of uniformity. No single instance can give a primary induction. In investigating the color of swans and crows we start with the well-established primary induction that color is, in animals, an uncertain quality. Combining this with the observation that these crows are black, we, of course, reach no conclusion. We have,

however, made a primary induction that all English crows are black; and this is correct. This leads us to remark that, in making an induction, it is necessary to define correctly the field under investigation. Having seen a thousand Chinamen in California, we conclude by induction that all Chinamen are, on the average, shorter than Americans. But when we learn that these men all came from one province, that of which Hong-Kong is the port, we change, not the induction, but the area of it; it concerns not Chinamen but one sort of Chinamen. So the induction "All crows are black" was correct for England, but not certainly for the whole world.

CHAPTER VII.

FACTS OF RESEMBLANCE.

THE earliest activities of the infant mind must be in observing single facts. But there is one recurring fact of relation which must soon force itself upon the attention; this is the resemblance between many of these single facts. As we say, in popular language, the same phenomenon is repeated. The word *same* thus used means merely that *a resembling* phenomenon comes. Meeting a multitude of similar phenomena, the mind at length forms a general concept, and finally invents a name which we call a common noun, as *man* or *tree*. The existence of such words depends upon the fact of the existence of numbers of objects recognized by the mind as similar.

And not only do objects resemble one another, but the changes and states of objects have also resemblances. The universe is perceived to be full of lines of resemblance or, to use a more common term, *Uniformity*. The phenomena about us at this moment are like the phenomena of yesterday and of a year ago to-day. "That which hath been is that which shall be; and that which hath been done is that which shall be done: and there is no new thing under the sun. Is there a thing whereof men say, See, this is new? it hath been already, in the ages which were before us."[1] As previously remarked, a universe in which every object should be

unique and every event a surprising novelty is perfectly conceivable; the conception contradicts no law of thought or, so far as we know, of being. But such is not the universe in which we live.

As one who enters, for example, a large store of pottery, soon discovers that much of the stock is in lots, and that this cup is like other cups, and that platter like other platters, so the observer of nature perceives that things are in lots and are passing through similar changes.

The possibility of language rests upon the recurrence of resemblances. Not only are objects alike, but their changes and relations are alike. The words used to describe the phenomena of yesterday are appropriate to-day. Nature may be divided into groups of similarities; and the phrase "Uniformity of Nature" embodies the opinion that things remain essentially similar to themselves, and of course, therefore, similar to the other things which at any time resemble them. Our belief in the uniformity of nature is the belief that the quantities and qualities of matter and force, and the faculties of mind, remain as they are. The integrity of the existing order is unimpaired.

Long inductive arguments may be constructed by successive judgments of resemblance, the intuitively known axiom that things that are equal to the same thing are equal to each other being the general major premise. These arguments are therefore mixed inductions. We will add two examples, one from the science of language and one from the science of geology.

The following analysis of an inductive argument is taken from Fowler's *Inductive Logic*: —

"The Method of Concomitant Variations is that which is most frequently employed in the Science of Language. It is found, for instance, that between two dissimilar words employed at different epochs to express the same idea may be interpolated a number of intermediate forms employed at intermediate epochs, which make the transition gradual and natural. From this circumstance it is inferred that the word used at the later epoch is derived from that used at the earlier epoch, certain tendencies of speech being regarded as the cause of the divergence. 'Thus, at first sight,' says M. Brachet, 'it is hard to see that *âme* is derived from *anima;* but history, our guiding-line, shows us that in the thirteenth century the word was written *anme*, in the eleventh *aneme*, in the tenth *anime*, which leads us straight to the Latin *anima*.' In this case there can be no doubt of the truth of the conclusion."[1]

This analysis we cannot at all accept. The proof that *âme* is the same as *anima* is based upon a number of successive observations of facts of resemblance. *Anima* and *anime* are so much alike in look, sound, and meaning, that we pronounce them the same; this is true also of *anime* and *aneme*, of *aneme* and *anme*, of *anme* and *âme*. We therefore construct the equation

$$\textit{anima} = \textit{anime} = \textit{aneme} = \textit{anme} = \textit{âme}.$$
$$\therefore \textit{anima} = \textit{âme}.$$

There is positively nothing here that varies concomitantly with the word *anima*. The explanation that "certain tendencies of speech are the cause of the divergence" is just like the explanation that opium causes sleep because "it has a soporific quality"; it explains nothing. The method generally employed in philological investigations is that of direct observation of resemblances. The proposition that *anima* and *âme* are the same word is an induction, because it is the

statement of a fact not directly observable and the statement is based upon observations. It is really a mixed induction; for it rests upon the axiom that things that are equal to the same thing are equal to each other.

Let us try to analyze the following argument for the evolution of the horse, taken from Le Conte's *Geology*:—

"*Genesis of the Horse.*—In conclusion, it will be interesting and instructive to run out one of these branches and show in more detail the genesis of one of the extreme forms. For this purpose we select the Horse, because it has been somewhat accurately traced by Huxley and by Marsh. About thirty-five or forty species of this family, ranging from the earliest Eocene to the Quaternary, are known in the United States. The steps of evolution may therefore be clearly traced.

"In the lower part of the Eocene basin (*Coryphodon beds*) of Green River is found the earliest known animal in the direct line of descent of the horse family, viz., the recently described *Eohippus* of Marsh. This animal had three toes on the hind-foot and four perfect, serviceable toes on the fore-foot; but, in addition, on the fore-foot an imperfect fifth metacarpal (splint), and possibly a corresponding rudimentary fifth toe (the thumb), like a dew-claw. Also, the two bones of the leg and fore-arm were yet *entirely distinct.* This animal was *no larger than a fox.* Next, in the *Middle Eocene* (Bridger beds), came the *Orohippus* of Marsh, an animal of similar size, and having similar structure, except that the rudimentary thumb or dew-claw is dropped, leaving only four toes on the fore-foot. Next came, in the *Lower Miocene*, the *Mesohippus*, in which the fourth toe has become a rudimentary and useless splint. Next came, still in the *Miocene*, the *Miohippus* of the United States and nearly allied Anchithere of Europe, more horse-like than the preceding. The rudimentary fourth splint is now almost gone, and the middle hoof has become larger; nevertheless, the two side-hoofs are still serviceable. The two bones of the leg have also become united, though still quite

distinct. This animal was about *the size of a sheep.* Next came, in the *Upper Miocene*, and *Lower Pliocene*, the *Protohippus* of the United States and allied *Hipparion* of Europe, an animal still more horse-like than the preceding, both in structure and size. Every remnant of the fourth splint is now gone; the middle hoof has become still larger, and the two side-hoofs smaller and shorter, and no longer serviceable, except in marshy ground. It was about the *size of the ass.* Next came, in the *Pliocene*, the *Pliohippus*, almost a complete horse. The hoofs are reduced to one, but the splints of the two side-hoofs remain to attest the line of descent. It differs from the true horse in the skull, shape of the hoof, the less length of the molars, and some other less important details. Last comes, in the *Quaternary*, the modern horse—*Equus.* The hoof becomes rounder, the splint-bones shorter, the molars longer, the second bone of the leg more rudimentary, and the evolutionary change is complete.

"Similar gradual changes, becoming more and more horse-like, may be traced in the shape of the head and neck, and especially in the gradually increasing length and complexity of structure of the grinding teeth."

"There can be no doubt that if we could trace the line of descent still further back we would find a perfect five-toed ancestor. From this normal number of five, the toes have been successively dropped, according to a regular law. In the *Perissodactyl* line first the thumb, No. 1, was dropped; then the little finger, No. 5; then the first and ring-fingers, Nos. 2 and 4, were shortened up more and more and finally disappeared, and only the middle finger, No. 3, remained in the modern horse. In the *Artiodactyl* line, after the dropping of No. 1, then Nos. 2 and 5 of the four-toed foot were shortened and gradually disappeared, and Nos. 3 and 4 remained in the Ruminants."

"From the earliest and most generalized types, therefore, to the present specialized types, the principal changes have been, first, from plantigrade to digitigrade; second, from short-footed digitigrade to long-footed digitigrade, *i.e., increasing elevation of the heel;* third, from five toes to one toe in the Horse, or two toes in Ruminants; and, fourth, from simple omnivorous molars to the complex herbivorous mill-stones of the Horse and the Ox.

"The change from plantigrade to digitigrade, with increasing elevation of the heel, when taken in connection with increasing size of the brain, and therefore presumably with increasing brain-power, shows a gradual improvement of structure adapted for speed and activity, and a *pari-passu* increase of nervous and muscular energy necessary to work the improved structure." [1]

The foregoing argument is just like that regarding the words *âme* and *anima; Eohippus* so closely resembles *Orohippus* that they must be the same; *Orohippus* must be the same as *Mesohippus; Mesohippus* must be the same as *Protohippus; Protohippus* is the same as *Pliohippus; Pliohippus* is the same as *Equus;* therefore the modern horse is the same as the Eohippus. The force of this argument will depend upon the strength of the impressions of resemblance made upon various minds. Professor Huxley regarded it as demonstrative.

[1] Pages 540–543.

CHAPTER VIII.

FACTS OF COEXISTENCE.

EVERY observer very quickly perceives that the various objects in the world may be divided into groups of permanent coexistences. Here is a mass of matter with specific gravity 19.34, a yellow color, malleable, ductile, etc., and there is another mass of matter in which the same phenomena coexist, and there is another. We call all these masses gold; and we say that gold is a *kind* of matter. Malleability, ductility, etc., are commonly called the properties of gold. But in truth we know absolutely nothing about gold except these properties. The weight does not possess the ductility, nor does the color possess the malleability; but the coexistence of all these phenomena *is* gold.

No approach has been made by science to any reason why certain phenomena permanently coexist; as, for instance, why the metal whose specific gravity is 19 34 should be yellow, and the metal whose specific gravity is 10.5 should be white. It is easy to say that all the properties probably depend upon some common fact of causation; but in the present state of science such a remark has no meaning.

A very large part of the work of science is in ascertaining the various natural kinds of objects. Mr. Mill magnifies the notion of cause and calls it "the root of the whole theory of induction." But it is plain that the notion of coexistence is an equally important root.

We cannot reason that such and such things *must* coexist; we can only discover that they do. This work has nothing to do with causation. It has nothing to do with the unknown. It does not proceed by inference. It is the orderly arrangement of what we know.

One vast attempt of Induction is to classify the objects in nature, that is, to discover and define all natural kinds. In this attempt it is soon perceived that there are groups within groups. Vegetables, for example, are a natural kind; but the vegetable kingdom may be subdivided into more limited kinds, and these kinds may be again subdivided.

A distinction is made between Natural and Artificial kinds. We may, for temporary convenience, divide objects according to some one property, as yellowness. And then gold and oranges and salmon will be of the same kind. Such a group is called an Artificial Kind. But Natural Kinds are so called because the objects which compose them resemble each other in a multitude of characteristics and appear, in fact, grouped together by nature. The great botanist Linnæus systematized plants according to the numbers of stamens and pistils, neglecting other features. This was a convenient, but highly artificial, arrangement; since it brought into the same order plants on the whole utterly diverse. Modern botany takes into consideration a multitude of particulars in stem, leaf, flower, and fruit; and so reaches a natural system. No classification is natural which depends in the least degree upon the caprice of the investigator; it must force itself upon all observers as existing in nature.

That there is a kind of objects which we may call plants and another kind of objects which we may call animals is generally admitted. But when we come to subdivide the animal and vegetable kingdoms, differences of opinion arise. It is obvious that certain individuals greatly resemble one another; they constitute natural groups, which may be called species. Certain species resemble one another; they may be associated in larger groups and called genera. So the genera may be grouped into orders, and the orders into classes.

Philosophers have discussed the question whether there is a point where natural subdivision ends. If there is such a point, then one of the smallest possible natural groups would be called an *infima species*. If, on the other hand, there be a group which cannot naturally be included in a larger, such a group would be called a *summum genus*.

The most interesting question in modern natural science is, whether the various natural groups of animals and plants — species, genera, orders, etc. — are naturally separated by distinct lines. The discussion has taken the form of an inquiry into the true nature of species. The main points in it can be conveniently presented in the words of Professor Asa Gray: —

"The ordinary and generally received view assumes the independent, specific creation of each kind of plant and animal in a primitive stock, which reproduces its like from generation to generation, and so continues the species. Taking the idea of species from this perennial succession of essentially similar individuals, the chain is logically traceable back to a local origin in a single stock, a single pair, or a single individual, from which all the individuals

composing the species have proceeded by natural generation. Although the similarity of progeny to parent is fundamental in the conception of species, yet the likeness is by no means absolute; all species vary more or less, and some vary remarkably — partly from the influence of altered circumstances, and partly (and more really) from unknown constitutional causes which altered conditions favor rather than originate. But these variations are supposed to be mere oscillations from a normal state, and in Nature to be limited if not transitory; so that the primordial differences between species and species at their beginning have not been effaced, nor largely obscured, by blending through variation. Consequently, whenever two reputed species are found to blend in Nature through a series of intermediate forms, community of origin is inferred, and all the forms, however diverse, are held to belong to one species. Moreover, since bisexuality is the rule in Nature (which is practically carried out, in the long run, far more generally than has been suspected), and the heritable qualities of two distinct individuals are mingled in the offspring, it is supposed that the general sterility of hybrid progeny interposes an effectual barrier against the blending of the original species by crossing.

"From this generally accepted view the well-known theory of Agassiz, and the recent one of Darwin, diverge in exactly opposite directions.

"That of Agassiz differs fundamentally from the ordinary view only in this, that it discards the idea of a common descent as the real bond of union among the individuals of a species, and also the idea of a local origin — supposing, instead, that each species originated simultaneously, generally speaking, over the whole geographical area it now occupies, or has occupied, and in perhaps as many individuals as it numbered at any subsequent period.

"Mr. Darwin, on the other hand, holds the orthodox view of the descent of all the individuals of a species not only from a local birthplace, but from a single ancestor or pair; and that each species has extended and established itself, through natural agencies, wherever it could; so that the actual geographical distribution of any species is by no means a primordial arrangement, but a natural result. He goes farther, and this volume [*The Origin*

of Species] is a protracted argument intended to prove that the species we recognize have not been independently created as such, but have descended, like varieties, from other species. Varieties, on this view, are incipient or possible species; species are varieties of a larger growth, and a wider and earlier divergence from the parent stalk; the difference is one of degree, and not of kind."[1]

"In applying his principle of natural selection to the work in hand, Mr. Darwin assumes, as we have seen: (1) Some variability of animals and plants in nature; (2) the absence of any definite distinction between slight variations and varieties of the highest grade; (3) the fact that naturalists do not practically agree, and do not increasingly tend to agree, as to what forms are species and what are strong varieties, thus rendering it probable that there may be no essential and original difference, or no possibility of ascertaining it, at least in many cases; also (4) that the most flourishing and dominant species of the larger genera on an average vary most (a proposition which can be substantiated only by extensive comparisons, the details of which are not given); and (5) that in large genera the species are apt to be closely but unequally allied together, forming little clusters round certain species — just such clusters as would be formed if we suppose their members once to have been satellites or varieties of a central or parent species, but to have attained at length a wider divergence and a specific character. The fact of such association is undeniable; and the use which Mr. Darwin makes of it seems fair and natural.

"The gist of Mr. Darwin's work is to show that such varieties are gradually diverged into species and genera through natural selection; that natural selection is the inevitable result of the struggle for existence which all living things are engaged in; and that this struggle is an unavoidable consequence of several natural causes, but mainly of the high rate at which all organic beings tend to increase."[2]

"Returning for a moment to De Candolle's article, we are disposed to notice his criticism of Linnæus's 'definition' of the term *species* (*Philosophia Botanica*, No. 157): '*Species tot numeramus quot diversae formae in principio sunt creatae*' — which he

[1] *Darwiniana*, p. 11. [2] *Ibid.*, p. 36.

declares illogical, inapplicable, and the worst that has been propounded. 'So, to determine if a form is specific, it is necessary to go back to its origin, which is impossible. A definition by a character which can never be verified is no definition at all.'

"Now, as Linnæus practically applied the idea of species with a sagacity which has never been surpassed, and rarely equaled, and, indeed, may be said to have fixed its received meaning in natural history, it may well be inferred that in the phrase above cited he did not so much undertake to frame a logical *definition*, as to set forth the *idea* which, in his opinion, lay at the foundation of species; on which basis A. L. Jussieu did construct a logical definition — 'Nunc rectius definitur perennis individuorum similium successio continuata generatione renascentium.' The fundamental idea of species, we would still maintain, is that of a chain of which genetically connected individuals are the links. That, in the practical recognition of species, the essential characteristic has to be *inferred*, is no great objection — the general fact that like engenders like being an induction from a vast number of instances, and the only assumption being that of the uniformity of Nature. The idea of gravitation, that of the atomic constitution of matter, and the like, equally have to be verified inferentially. If we still hold to the idea of Linnæus, and of Agassiz, that existing species were created independently and essentially all at once at the beginning of the present era, we could not better the propositions of Linnæus and of Jussieu. If, on the other hand, the time has come in which we may accept, with De Candolle, their successive origination, at the commencement of the present era or before, and even by derivation from other forms, then the '*in principio*' of Linnæus will refer to that time, whenever it was, and his proposition be as sound and wise as ever."[1]

". . . Species, as I have said (in *Silliman's Journal* articles) are not facts or things, but judgments, and, of course, fallible judgments. How fallible, the working naturalist knows and feels more than any one else."[2]

Inductive *Classification* is the orderly arrangement of things in their natural groups or kinds. We may

[1] *Darwiniana*, p. 201. [2] *Letters*, p. 657.

classify mental states or social movements, as well as physical forces and material objects, minerals, plants, and animals.

Nomenclature is a system of names for the various things classified. In Botany the name of a plant is always in Latin, and consists of the name of the genus, followed by the name of the species, as *Viola blanda*, sweet white violet. Unfortunately, no one has yet thought of any way of forming botanical names from natural characteristics, so that the nomenclature, also, may be natural. On the contrary, the names of genera and species have been assigned by discoverers for trivial and often ridiculous reasons, and the whole scientific world has been forced to perpetuate the memory of silly caprices. This is an ignominy which no disciplined mind can think of without indignation. In Chemistry the names of substances are compounded of those of their elements, with prefixes and terminations suggesting their proportions. Chemical nomenclature is the best we have, but its development has lagged behind the general progress of the science. Mineralogy needs nothing more than an adequate nomenclature. A system of names suggesting both crystallography and chemical composition would be far preferable to smithite, jonesite, and brownite.

Terminology is the precise vocabulary used in describing the parts, qualities, and actions of the objects of science. Botany has a wonderfully copious vocabulary. This vocabulary is strictly inductive ; the meaning of each word is fixed by direct examination of typical specimens. Such words as serrate, dentate, crenate, runcinate, bipinnatifid, etc., are defined by exhibiting

to the learner the parts of plants which they describe, and each is ever afterwards used in precisely the same sense. By the use of a proper terminology, scientists can convey to one another, in a few words, accurate descriptions of phenomena, which pages of popular phraseology would leave still obscure.

CHAPTER IX.

FACTS OF CAUSATION AND FACTS OF SUCCESSION.

It is a matter of observation that things in this universe react upon one another. It is further observed that after such reactions the things sometimes appear in new forms. This property of reacting, or of presenting new forms, is called the power of Causation. The several reactions of things are called events. The things which react are said to be the causes of these events. If things appear in new forms, they are said to be, in their antecedent forms, the causes of themselves in their subsequent forms.

This power of affecting, or being affected, is an ultimate property of things. It is one of those ultimate properties the coexistence of which constitutes the existing order. Science never attempts the explanation of ultimate properties; or rather, when science finds anything inexplicable she calls it ultimate.

Things exist in space, and events occur in time. Time is marked and estimated by the succession of events. And these events are seen to have often a certain relation to one another. Just as there are certain uniform coexistences of phenomena, so there are certain uniform successions. Yellowness and ductility present themselves simultaneously in gold; contact with red-hot iron and pain in the flesh present them-

selves as antecedent and consequent events. The events of history seem to come in chains, one link drawing on the next. So impressed have some philosophers been with this appearance of concatenation among events, that they have attempted to define causation itself in terms of succession, and they have thus brought great confusion into the science of inductive logic.

Perhaps it may be easier to define the difficult word Cause, and to show the relation of causation and succession, in connection with a concrete example. We will, therefore, take an instance classic in the history of inductive science, one of the experiments of the illustrious Count Rumford upon heat. The illustration will be useful not only here but in subsequent chapters, and it is so interesting that we will give it at length, and in the Count's own words.

"Being engaged lately in superintending the boring of cannon in the workshops of the military arsenal at Munich, I was struck with the very considerable degree of heat which a brass gun acquires, in a short time, in being bored; and with the still more intense heat, much greater than that of boiling water, as I found by experiment, of the metallic chips separated from it by the borer. From whence comes the heat actually produced in the mechanical operation above-mentioned? . . .

". . . Taking a cannon, a brass six-pounder, cast solid, and rough as it came from the foundry, and fixing it horizontally in the machine used for boring, and at the same time finishing the outside of the cannon by turning, I caused its extremity to be cut off; and, by turning down the metal in that part, a solid cylinder was formed, $7\frac{3}{4}$ inches in diameter, and $9\frac{8}{10}$ inches long; which, when finished, remained joined to the rest of the metal, that which, properly speaking, constituted the cannon, by a small cylindrical neck, only $2\frac{1}{5}$ inches in diameter, and $3\frac{8}{10}$ inches long. This short cylinder, which was supported in its horizontal position, and

turned round its axis, by means of the neck by which it remained united to the cannon, was now bored with the horizontal borer used in boring cannon; but its bore, which was 3.7 inches in diameter, instead of being continued through its whole length, 9.8 inches, was only 7.2 inches in length; so that a solid bottom was left to this hollow cylinder, which bottom was 2.6 inches in thickness.

"The cylinder being designed for the express purpose of generating heat by friction, by having a blunt borer forced against its solid bottom at the same time that it should be turned round its axis by the force of horses, in order that the heat accumulated in the cylinder might from time to time be measured, a small round hole, 0.37 of an inch only in diameter, and 4.2 inches in depth, for the purpose of introducing a small cylindrical mercurial thermometer, was made in it, on one side, in a direction perpendicular to the axis of the cylinder, and ending in the middle of the solid part of the metal which formed the bottom of its bore.

"*Exper. 3.*—A quadrangular oblong deal box, water-tight, $11\frac{1}{2}$ English inches long, $9\frac{4}{10}$ inches wide, and $9\frac{6}{10}$ inches deep, being provided, with holes or slits in the middle of each of its ends, just large enough to receive, the one, the square iron rod to the end of which the blunt steel borer was fastened, the other, the small cylindrical neck which joined the hollow cylinder to the cannon; when this box was put into its place it was fixed to the machinery, in such a manner that its bottom being in the plane of the horizon, its axis coincided with the axis of the hollow metallic cylinder; it is evident, from the description, that the hollow metallic cylinder would occupy the middle of the box, without touching it on either side; and that, on pouring water into the box, and filling it to the brim, the cylinder would be completely covered, and surrounded on every side, by that fluid. And further, as the box was held fast by the strong square iron rod which passed, in a square hole, in the centre of one of its ends, while the round or cylindrical neck, which joined the hollow cylinder to the end of the cannon, could turn round freely on its axis in the round hole in the centre of the other end of it, it is evident that the machinery could be put in motion, without the least danger of forcing the box out of its place, throwing the water out of it, or

deranging any part of the apparatus. Everything being ready, I proceeded to make the experiment I had projected, in the following manner.

"The hollow cylinder having been previously cleaned out, and the inside of its bore wiped with a clean towel till it was quite dry, the square iron bar, with the blunt steel borer fixed to the end of it, was put into its place; the mouth of the bore of the cylinder being closed at the same time, by means of the circular piston, through the centre of which the iron bar passed. The box was then put in its place, and the joinings of the iron rod, and of the neck of the cylinder, with the two ends of the box, having been made water-tight by means of collars of oiled leather, the box was filled with cold water (viz., at the temperature of 60°), and the machine was put in motion. The result of this beautiful experiment was very striking, and the pleasure it afforded me amply repaid me for all the trouble I had had, in contriving and arranging the complicated machinery used in making it. The cylinder, revolving at the rate of about 32 times in a minute, had been in motion but a short time, when I perceived, by putting my hand into the water, touching the outside of the cylinder, that heat was generated; and it was not long before the water which surrounded the cylinder began to be sensibly warm. At the end of 1 hour, I found, by plunging a thermometer into the water in the box (the quantity of which fluid amounted to 18.77 lb. avoirdupois, or 2¼ wine gallons), that its temperature had been raised no less than 47 degrees, being now 107° of Fahrenheit's scale. When 30 minutes more had elapsed, or 1 hour and 30 minutes after the machinery had been put in motion, the heat of the water in the box was 142°. At the end of 2 hours, reckoning from the beginning of the experiment, the temperature of the water was found to be raised to 178°. At 2 hours 20 minutes it was at 200°; and at 2 hours 30 minutes it actually boiled.

"It would be difficult to describe the surprise and astonishment expressed in the countenances of the by-standers, on seeing so large a quantity of cold water heated, and actually made to boil, without any fire. Though there was, in fact, nothing that could justly be considered as surprising in this event, yet I acknowledge fairly that it afforded me a degree of childish pleasure, which,

were I ambitious of the reputation of a grave philosopher, I ought most certainly rather to hide than to discover."[1]

Here is a phenomenon — the heat of the water in Count Rumford's box. Let us inquire now what we are doing when we seek for its cause.

Plainly the motion of the cylinder was an antecedent of the heat in the water in some pre-eminent and unique sense. Heat is an energy; it could not appear in the water unless it passed out of some other material in which it previously existed as motion, or in some other mode. We know this by a very broad primary induction. Indeed, we here come upon the grand generalization of the conservation, or, to use a better word, the persistence, of energy. A multitude of experiences have led men to believe that whenever energy newly appears, it has existed previously in another mode or in other materials. The necessary antecedent of energy in one mode or one body is the same energy in a previous mode or in a different body. All machinery is contrived on this principle; at some point energy is introduced, and it is then transferred or transformed, so that we get light, heat, electricity or motion, as desired. From the standpoint of the physicist the whole cause of the heat of the water was the motion of the cylinder. The degree of heat gained by the one was exactly measured by the amount of motion lost by the other. There was only a transfer of energy. When in popular language we say that the motion is the cause of the heat, the physicist says that the motion *is* the heat, only in another mode. The law of causation, when applied to energy, is only the fact of persistence.

When we say that energy here must have had a cause, we only mean that, having no reason to think that new energy has been added to the world, we must consequently assume that this apparently new energy is only the old in a new mode. When, therefore, we inquire for the cause of energy, we may be merely inquiring, Where and in what mode was this energy previously? The answer to the question names the *Energetic Cause.* If it be asked, What was the cause of the motion in the cylinder? the answer is, The motion of the horses. The energy might be further traced through physiological action in the bodies of the horses, and then through physiological action in the growth of the grain and hay upon which they had fed, until at last we should reach the sun's light and heat. One thing is now agreed upon, that the stream of energy in the world, like the Nile in the desert, receives no tributaries, but simply flows on identical with itself, its transformations depending upon the qualities and collocations of matter.

But why did motion in the cylinder become heat in the water? Here a cause is demanded in a different sense. The inquiry is for those properties and collocations of matter which occasioned a transformation. The arrangement was such that motion could not be communicated from the cylinder to any other part of the apparatus ; the motion, therefore, according to a permanently coexisting property, transformed itself into heat. The different properties of energy and the different properties of the several sorts of matter in relation to energy, we know by primary inductions which cannot be resolved into simpler generalizations ; they

are the ultimate facts of the world. The motion of the cylinder changed into heat when the cylinder found itself in connection with certain other masses of matter of certain qualities and collocations. What were these? The answer to this question will name the *Conditional Cause.* It will describe the environment in which the transformation took place. While the motion was the cause, and in one sense the sole cause, of the heat, it is yet true that, if left to itself, it would never have changed to heat; it would have continued eternally as motion. The peculiar environment, then, is, in one sense, the sole cause of the heat, since but for that there would have been nothing but motion.

If, instead of investigating the cause of the *energy* in this experiment, we should investigate the cause of the *matter*, asking not, What is the cause of the heat? but, What is the cause of the water? we could go back in the same way along an unbroken line of materials. The cause of the water in the box was water in a river or a well, the cause of that was water in the clouds, the cause of that was the two gases oxygen and hydrogen, and so on. There is a persistence of matter as there is a persistence of force. When we ask for the cause of matter in one form or place we may be merely inquiring, Where and in what form was this matter previously? The answer will name for us the *Material Cause.* Or we may seek the conditional cause for the matter, asking, What was the environment in which this matter came to be as it is?

According to one of the grandest primary inductions of modern science, the two lines of energetic and material causation are absolutely continuous and com-

plete. In the physical world nothing is added and nothing is lost; but the sum of things persists in its integrity.

But approaching the analysis upon a different line, we find that Count Rumford himself was in a unique sense the cause of the heat. It was his *choice* to perform an experiment that eventuated in the heating. The Will of Count Rumford was neither the material cause, nor the energetic cause, nor the conditional cause of the heating of the water. It was the cause in a sense higher than any of these. We will call it the *Volitional Cause.* The relation of will to the physical universe is peculiar. It cannot originate matter or energy; but it can direct the transformation of a certain amount of the energy of the body. By taking advantage of this power, the Count originated a new chain of events, which terminated in the heating. When in pursuing a chain of events backward we come to a will, the mind recognizes a super-physical intervention; the man is responsible, and if the events are injurious to the public welfare, he must pay the penalty. All of the power now in my arm was yesterday, or previously, in the beef, potatoes, and other food on the table. If I allow my arm to hang limp, physiological and chemical transformations will go forward in natural course, and the energy now potentially mine will pass away. For a brief space this stored energy lies subject to my order, like money in a bank. I can will its transformation into motion; but I cannot increase or diminish its amount. A party of Arctic explorers, after many days of starvation and hard labor, attempted to draw their boat out of the water; all

grasped it and at the accustomed signal put forth the usual volition for simultaneous action. But no effect followed; their wills were as usual, but there was no stored energy for those wills to transform.

Lotze has said :—

"What constitutes the absolute authority of the causal law is not that every part of the finite sum of things actual must in the finite sphere be produced by fixed causes, according to universal laws, but that each constituent once introduced into this actual course continues to act according to these laws. We commonly speak only of every effect having its cause, but we should on the contrary lay stress chiefly on the other form of the proposition — every cause has invariably its effect. The meaning of causality consists not indeed exclusively, but (it seems to me) in its more essential part, in its securing to every element of the actual world, springing from no matter what source, means of acting energetically on the other constituents of the world to which it belongs, at the same time preventing it from acting within that world otherwise than in harmony with the universal laws regulating all that takes place in it. Thus the world would be like a vortex swelled by new waves from all sides, which it does not itself attract or produce, but which, once within it, are forced to take part in its motion. We have another example of the same process in the relation of our own soul to our bodily organs; the soul evolves from itself resolutions, starting-points for future movements; none of them needs to be determined by and founded on phenomena in the bodily life on which it reacts; but each, at the moment of its passing into that life, subordinates itself to the peculiar laws of the latter, and generates so much or so little motion and force as these permit of — motion too in the direction which they prescribe and no other. The universal course of things may at every moment have innumerable beginnings whose origin lies outside of it, but can have none not necessarily continued within it."[1]

[1] *Microcosmus*, p. 260. I am indebted for this quotation to my colleague, Professor Henry C. King.

Lotze is wrong in saying that the will generates force and thus adds to the sum of physical things; but he is right in saying that the spiritual acts upon the physical to transform energy, and that, once transformed, the energy goes on acting according to the uniformity of its coexistences, or what are commonly called its laws. The beginnings which lie outside of the universal course of physical things are volitions, and their effects are transformations. The will is not the energetic cause any more than it is the material cause; it is a cause *sui generis*, the volitional cause.

So far we have spoken of Things as the causes of Things. Matter in one form or situation is the cause of the same matter differently disposed; energy as motion is the cause of the same energy as heat; a Will, by transforming the vital energy of the body into various motions, brings together matter and energy in new combinations. The causes so far considered are entities and the effects are entities.

But things may also cause Events. Every kind of matter and every kind of energy has uniform properties; it reacts in certain ways upon other things. These reactions are called its effects. In this aspect each thing may be called an *Efficient Cause*. In our experiment there were certain events, the moving of the cylinder, the heating of the water, etc. The energy concerned was the efficient cause of these events. Count Rumford was also an efficient cause of the events, since the action of his will was concerned in their production.

But an entirely different line of investigation might have been pursued; leaving things entirely out of view,

we might have attended solely to Events. One event may be said to cause another event.

The ultimate qualities of matter and force remaining as they are, in every possible collocation of things (except that of perfect equilibrium), a certain reaction is inevitable. If, for example, it be the nature of water to absorb heat, then when a quantity of water, as in Count Rumford's box, finds itself in contact with a hot cylinder, the absorption will inevitably take place. But every physical event is simply a new distribution of forces and materials: hence (the properties of things remaining as they are) a further reaction is inevitable. Thus, like the bits of colored glass in a kaleidoscope, the things in the physical world fall at each moment into new relations each of which, if there be no intervention, is the necessary opportunity for the next. Thus one event is said to cause another event. This inevitableness of physical reaction is the very fact which opens the door for the interventions of will. By transforming the energy of the body into motion, and thus changing the collocations of a few things, men shunt on to other tracks the trains of events and transform the whole complexion of history.

Recurring to the experiment, we may say that the moving of the cylinder was an event which caused the heating of the water, another event. But when rigid definition is attempted it is found surprisingly difficult to define an event. The event was not merely the heating of some water, but the heating of it in a certain box at a particular time and place and in peculiar circumstances. When all the circumstances, even the most remote, are taken into the account, they include

the situation of the whole universe. The successive events of history are the successive collocations of the totality of things. While this is true, the general facts of the universe are so permanent and so similar as factors in all events that they may be practically disregarded, and the more detailed and proximate elements alone considered as constituting an event. The name *Historical Cause* may be given to one event when regarded as the cause of another event. Notice how different is the sense of the word cause here from that which it bears when applied to things. An event is the cause of another event only in the sense that its occurrence is the coming of materials and forces into such a collocation that they are certain to react again in a particular way. The turning of the cylinder was an event; but if a cylinder be turning under such circumstances, it is the ultimate property of motion to become heat and of water to absorb heat; consequently the turning was the historical cause of the heating. Between events there can be no connection but that of succession; they are but the coming of things into collocations. The continuity is in the things, and each new event arises out of the ultimate properties which coexist in things. There is no efficiency in an event, or tendency of any kind to beget another event; but after each event there is a new possibility; and, the properties of matter and force remaining persistent, whatever is possible is inevitable. When a siphon has been filled with water and is left open, the force of gravity will cause the water to flow until the short end of the tube is exposed. The filling and opening of the siphon are events which leave a situation in which

gravity can cause a flow, but those events have no efficiency in inducing the flow. Popularly, the falling of a spark into a powder magazine is said to cause an explosion. Historically this is correct; when a spark so falls there is a collocation in which heat will pass into materials which at that temperature will enter into new chemical combinations accompanied by that sudden distension which is called an explosion. The falling of the spark is the historical cause, the spark and the powder are the material cause, the heat of the spark and the chemical affinity of the substances constituting the powder are the energetic cause.

In a loose way, an event may be said to be the cause of a *State*. A blackened pile of ruins may be pointed out as the effects of a conflagration, or the splintered trunk of a tree may be called the effect of lightning. But, strictly speaking, states have no causes. No reason need be given why things remain as they are; for obviously, unless something happens, nothing happens. If a ball is in motion, and no obstruction presents itself, we do not have to account for the motion; but if the ball stops, there is an event to account for. An event is the coming of things into a new situation. If in this situation there is a comparative equilibrium of forces, the situation may indefinitely continue. If the breaking of a dam allows the water to flow out, the event of the breaking is the historical cause of the event of the emptying. But the reservoir may never be filled again; the state of emptiness may continue permanently, and the cause for it will be said to be the breaking of the dam. This, however, is a very inexact use of language. Emptiness

is a mere negation. The thing to be accounted for is the change from the previous fullness. The breach in the dam leaves the water free to move, under the *efficient cause*, *gravity*; once empty, the reservoir remains so without needing a cause of any kind.

Human history moves on in the midst of a complex of materials and forces which have certain properties, and which are certain, in each given collocation, to react in one particular way. Physically speaking, whatever at any moment is possible is certain. There is no contingency, no alternative. A weight free to fall falls; a bit of iron in a jar of oxygen and sufficiently hot burns. Each event makes *possible* the next, and in that sense may be said to make it *certain*. But the human will has the wonderful power of choosing which of several events shall come to pass. It cannot create nor annihilate matter or energy; but it can transform the energy of the body into motion. Thus materials and forces may be brought into collocations which would not otherwise have arisen and, although reacting according to their nature, may produce events very different from what would otherwise have been. The volitions of will do not arise by necessity out of foregoing situations; consciousness affirms freedom, and it is here our only organ of observation. The motives in view of which will acts are *Occasional Causes*, not efficient causes. In tracing the course of events in human history we find this interweaving of physical necessities and free volitions like the warp and woof of a tapestry: to unravel it, is the task of the historian in his search for the connections of things. A passage from the *Life and Letters of Charles Darwin* will show

how slight may be the connection between two events which are yet in a certain sense cause and effect :—

"The following story shows what good guesses my father could make. Lord Shelburne, afterward the first Marquis of Lansdowne, was famous (as Macaulay somewhere remarks) for his knowledge of the affairs of Europe, on which he greatly prided himself. He consulted my father medically, and afterward harangued him on the state of Holland. My father had studied medicine at Leyden, and one day while there went on a long walk into the country with a friend who took him to the house of a clergyman (we will say the Rev. Mr. A——, for I have forgotten his name), who had married an Englishwoman. My father was very hungry, and there was little for luncheon except cheese, which he could never eat. The old lady was surprised and grieved at this, and assured my father that it was an excellent cheese, and had been sent to her from Bowood, the seat of Lord Shelburne. My father wondered why a cheese should be sent to her from Bowood, but thought nothing more about it until it flashed across his mind many years afterwards, whilst Lord Shelburne was talking about Holland. So he answered, 'I should think from what I saw of the Rev. Mr. A——, that he was a very able man, and well acquainted with the state of Holland.' My father saw that the Earl, who immediately changed the conversation, was much startled. On the next morning my father received a note from the Earl, saying that he had delayed starting on his journey, and wished particularly to see my father. When he called, the Earl said, 'Dr. Darwin, it is of the utmost importance to me and to the Rev. Mr. A—— to learn how you have discovered that he is the source of my information about Holland.' So my father had to explain the state of the case, and he supposed that Lord Shelburne was much struck with his diplomatic skill in guessing, for during many years afterwards he received many kind messages from him through various friends. I think that he must have told the story to his children; for Sir C. Lyell asked me many years ago why the Marquis of Lansdowne (the son or grandson of the first marquis) felt so much interest about me, whom he had never seen, and my family. When forty new mem-

bers (the forty thieves, as they were then called) were added to the Athenæum Club, there was much canvassing to be one of them; and without my having asked any one, Lord Lansdowne proposed me and got me elected. If I am right in my supposition, it was a queer concatenation of events that my father not eating cheese half-a-century before in Holland led to my election as a member of the Athenæum."[1]

This "queer concatenation" is a fair example of causation in human history. Dr. Darwin's not eating cheese was the cause of his son's being elected into the club, that is, it was a link in a chain of events, some of which were volitions and some physical necessities, and the election was a subsequent link. The very triviality of this incident makes it especially good as an illustration. We have termed the motives upon which the will reacts, occasional causes, since they furnish the occasions, but not the efficiency, of causation. Here may be distinguished the *Formal* Cause, or idea viewed as a distinct conception; and *Final* Cause, the end, design, or object for which anything is done.

A *Negative Cause* is the absence of anything which if present would have prevented a given phenomenon. It is obvious that any particular event would not have happened if it had been prevented. The absence of a violent earthquake was a negative cause of the heating of the water in Count Rumford's experiment. But the word *cause* is used here in a sense very remote from that which it bears in other connections. A little boy said that salt was the cause of a bad taste in potatoes when he did not put it on them. That is, in the absence of salt, potatoes have an insipid taste. To say "negative cause" is, indeed, to make a contradiction

[1] Page 14.

in the adjective; it is equivalent to "inactive agent." But in common life, and in ordinary discourse, it is convenient, when the absence of some usual factor in a collocation of things gives opportunity for some unusual event. Thus the absence of the signalman is said to be the negative cause of the railway accident, and the sleep of the sentinel is said to be the negative cause of the defeat of the army. A will may be a negative cause in a more active sense, since refusal to interfere, when interference is possible, involves at least consent to the occurrence of the event; hence, neglect may be criminal.

Let us sum up now the results of our discussion of Causation. The cause of a phenomenon is that which gives it existence. Every mass of matter has a material cause, which is the same matter in a previous place or state. Every portion of energy has an energetic cause, which is the same energy in a previous mode or another mass of matter. Every portion of matter or of energy has a conditional cause for its present place and form, in the environment which has reacted upon it. One peculiar factor in the conditional cause may be a will whose reaction transforms energy, thus constituting a volitional cause. A will acts in view of motives, occasional causes. Events are the reactions of things, which are their efficient causes.

Is the law of causation, namely, that every phenomenon depends upon some other phenomenon, intuitively known? The question is too vague to admit of a single answer. That matter and energy persist is a very recently made primary induction from experience. The law of material and of energetic causation is, then,

not intuitively known. That every *event* has a thing as its cause is known by a mere analysis of the meaning of the terms employed, since events are the reactions of things, and there cannot be an action without an agent. That every event has some other event as its necessary historical cause is not proved either from intuition or experience. Gravitation causes the earth to revolve around the sun ; the causation is in the bodies and forces, not in any previous event. That a will acts in view of final and formal causes is plain ; but that, like matter, it always reacts in precisely the same way under the same stimulus is contradicted by consciousness.

Do we know intuitively that "like causes always produce like effects" ? The difficulty with this question is that the words cause and effect are correlatives, and must be defined in terms of each other. An affirmative answer would teach nothing but an identical proposition. The truth which the dictum seeks to express is better stated thus: We know by a primary induction that the existing order persists, and while things remain as they are they will act as they do. How long the existing order will continue we cannot even guess, since all of our reasoning about things is based upon primary inductions from the existing order. But neither have we any ground for expecting an end.

The foregoing discussion of facts of causation makes it easy to deal with facts of succession. The facts of succession are seen to be all secondary. They are incidental results of facts of causation. Succession is not at all of the essence of causation. Gravitation keeps the earth revolving around the sun. This effect

is the operation of a permanent cause — the two bodies reacting upon each other; but there is no succession of cause and effect. Just so the needle is attracted toward the pole by a permanent cause, magnetism. Succession belongs to events in their mutual relations, not to things; but things are the only efficient causes. Things coexist and persist; they do not follow one another in time. It is true that between a thing and the material cause of it, that is, the same matter in an earlier form, there is a sort of succession. Ice may cause water, and water may cause steam; one form follows another. But this is not at all that invariable sequence which constitutes a fact of succession. Things must be simultaneous with their own reactions. Professor Davis remarks: —

> "But it would, perhaps, be more accurate to say that every cause is simultaneous with its effect. For cause and effect are correlatives — neither can exist without the other; they exist only as they coexist. A cause cannot be so named, except by anticipation, until there is an effect; nor an effect, except by reference to what has already occurred, after the change or event has taken place. The order of succession is logical, not temporal."[1]

The fact that events occupy time, and the fact that each event leaves a new collocation of things which makes a new reaction possible — these two facts give us the chain of history. Between two events, one of which is the historical cause and the other the historical effect, there is no other connection than that, after the first, things are in such a collocation that they cause the second. An event has as many possible historical causes as there are possible ways of bringing

things into the requisite collocation. For example, ice when in contact with salt at ordinary temperatures of the air rapidly liquefies. The efficient cause of the event, liquefaction, is the two bodies ice and salt, and they are simultaneous with it. But the historical cause of the event is any possible action which can bring the substances together, and thus open the possibility for their reaction. All facts of succession are thus consequences of facts of coexistence and causation. A succession is known empirically, and is susceptible of analysis into simpler elements. We may always hope to be able to tell why a given succession obtains, in terms of facts of coexistence and causation. Yet many successions were empirically known ages before they were analyzed, and many well-known successions still remain unanalyzed. Many persons are familiar with that historical succession of events which always ends in the production of ice-cream, who have never thought of the operation of the efficient causes.

CHAPTER X.

MR. MILL'S DOCTRINE OF CAUSATION.

MR. JOHN STUART MILL is unquestionably the most eminent and influential of all writers upon inductive logic since Bacon. His work is the most elaborate that has appeared, and his teachings, on many points, have been generally adopted. The science owes to him a very great debt. No one can justly claim to understand modern inductive logic who has not thoroughly studied Mr. Mill's doctrine of causation. In this chapter we shall seek to present this doctrine in a condensed form, but as nearly as possible in Mr. Mill's own words.

According to Mr. Mill, the notion of cause is "the root of the whole theory of Induction." In this view he is followed by later writers. For example, Professor Davis says: "Such principles are evolved from the intuitive fact of causation, the root of all induction, and that which gives it validity."

Yet Mr. Mill also holds that our first step in the knowledge of nature is to discover the particular uniformities; then that we generalize the uniformity of these uniformities; and that this uniformity of uniformities is the law of the uniformity of nature. Strangely enough, the uniformity of nature is, to Mr. Mill, the same as the law of causation. "Whatever be the most proper mode of expressing it," he says, "the proposition that the course of nature is uniform, is the fundamental principle, or general axiom of induction."

It is a difficulty with this view that if inductive logic have to do solely with causation, the vast mass of facts of coexistence and of resemblance is left unprovided for. Such sciences as mineralogy and botany deal mainly with facts of coexistence, yet they are commonly considered purely inductive. The definition provides no rightful place in inductive logic for the original discovery of uniformities; all of this work has been done before induction proper can begin. Moreover, the law of uniformity of uniformities is something very much wider than the law of causation. It is largely concerned with the uniformities of coexistence. Thus we know the persistence of the several kinds of matter and the persistence of energy by so many independent primary inductions from multitudinous observations of the several things. We not only know that a magnet attracts iron, which is a fact of causation; but that iron remains iron, that is, that that assemblage of coexisting qualities which we call iron persists, which is not a fact of causation.

Mr. Mill does not regard the uniformity of nature as the immediate major premise in every inductive argument." "It is not a necessary condition that the uniformity should pervade all nature. It is enough that it pervades the particular class of phenomena to which the induction relates." That is, we may make a valid secondary induction from any sound, though limited, primary induction, without reference to the soundness of the root of the whole theory. In fact the so-called root is only a generalization of more limited primary inductions.

Mr. Mill's definition of Cause is as follows: —

"We may define, therefore, the cause of a phenomenon, to be the antecedent, or the concurrence of antecedents, on which it is invariably and unconditionally consequent."

In making this definition Mr. Mill began with no analysis of the different ways in which the word cause is used. He did not inquire whether the so-called effect is a thing or a reaction, or the so-called cause a material, an energy, a circumstance, a will, or a prior event. Starting with the notion of succession as fundamental, he attempted to frame a definition so general as to cover all values of the unknown terms of the relation. Yet it is plain in the course of his elaborate discussions that, generally, for him the "phenomenon" in the definition is a reaction, an event. For he says: —

"And the universality of the law of causation consists in this, that every consequent is connected in this manner with some particular antecedent, or set of antecedents. Let the fact be what it may, if it has begun to exist, it was preceded by some fact or facts, with which it is invariably connected. For every event there exists some combination of objects or events, some given concurrence of circumstances, positive and negative, the occurrence of which is always followed by that phenomenon." "On the universality of this truth depends the possibility of reducing the inductive process to rules."[1]

For Mr. Mill, then, an effect is an event, and a cause is a number of things in a collocation and with a history.

In this complex of things, relations, and history, to which alone Mr. Mill, when speaking strictly, gives the name cause, all the factors are absolutely equal. The

[1] *Logic*, p. 237.

difference between efficient causes and conditions is denied. Mr. Mill says :—

"It is seldom, if ever, between a consequent and one single antecedent, that this invariable sequence subsists. It is usually between a consequent and the sum of several antecedents; the concurrence of them all being requisite to produce, that is, to be certain of being followed by, the consequent. In such cases it is very common to single out one only of the antecedents under the denomination of Cause, calling the others merely Conditions. Thus, if a man eats of a particular dish, and dies in consequence, that is, would not have died if he had not eaten of it, people would be apt to say that eating of that dish was the cause of his death. There need not, however, be any invariable connection between eating of the dish and death; but there certainly is, among the circumstances which took place, some combination or other upon which death is invariably consequent: as, for instance, the act of eating of the dish, combined with a particular bodily constitution, a particular state of present health, and perhaps even a certain state of the atmosphere; the whole of which circumstances, perhaps, constituted in this particular case the *conditions* of the phenomenon, or in other words, the set of antecedents which determined it, and but for which it would not have happened. The real Cause, is the whole of these antecedents; and we have, philosophically speaking, no right to give the name of cause to one of them, exclusively of the others. What, in the case we have supposed, disguises the incorrectness of the expression, is this: that the various conditions, except the single one of eating the food, were not *events* (that is, instantaneous changes, or successions of instantaneous changes) but *states*, possessing more or less of permanency; and might, therefore, have preceded the effect by an indefinite length of duration, for want of the event which was requisite to complete the required concurrence of conditions: while as soon as that event, eating the food, occurs, no other cause is waited for, but the effect begins immediately to take place: and hence the appearance is presented of a more immediate and closer connection between the effect and that one antecedent, than between the effect and the remaining conditions. But though we

may think proper to give the name of cause to that one condition the fulfillment of which completes the tale and brings about the effect without further delay, this condition has really no closer relation to the effect than any of the other conditions has. All the conditions were equally indispensable to the production of the consequent; and the statement of the cause is incomplete, unless, in some shape or other, we introduce them all. A man takes mercury, goes out of doors, and catches cold. We say, perhaps, that the cause of his taking cold was exposure to the air. It is clear, however, that his having taken mercury may have been a necessary condition of his catching cold; and though it might consist with usage to say that the cause of his attack was exposure to the air, to be accurate we ought to say that the cause was exposure to the air while under the effect of mercury.

"If we do not, when aiming at accuracy, enumerate all the conditions, it is only because some of them will, in most cases, be understood without being expressed, or because for the purpose in view they may, without detriment, be overlooked. For example, when we say, the cause of a man's death was that his foot slipped in climbing a ladder, we omit, as a thing unnecessary to be stated, the circumstance of his weight, though quite as indispensable a condition of the effect which took place."

"In all these instances the fact which was dignified by the name of cause, was the one condition which came last into existence. But it must not be supposed that in the employment of the term, this or any other rule is always adhered to. Nothing can better show the absence of any scientific ground for the distinction between the cause of a phenomenon and its conditions, than the capricious manner in which we select from among the conditions that which we choose to denominate the cause. However numerous the conditions may be, there is hardly any of them which may not, according to the purpose of our immediate discourse, obtain that nominal pre-eminence."[1]

"Thus we see that each and every condition of the phenomenon may be taken in its turn, and with equal propriety in common parlance, but with equal impropriety in scientific discourse, may be

[1] *Logic*, pp. 237, 238.

spoken of as if it were the entire cause. And in practice that particular condition is usually styled the cause whose share in the matter is superficially the most conspicuous, or whose requisiteness to the production of the effect we happen to be insisting upon at the moment. So great is the force of this last consideration, that it often induces us to give the name of cause even to one of the negative conditions. We say, for example, the cause of the army's being surprised was the sentinel's being off his post. But since the sentinel's absence was not what created the enemy, or made the soldiers to be asleep, how did it cause them to be surprised? All that is really meant is, that the event would not have happened if he had been at his duty. His being off his post was no producing cause, but the mere absence of a preventing cause: it was simply equivalent to his non-existence. From nothing, from a mere negation, no consequences can proceed. All effects are connected, by the law of causation, with some set of *positive* conditions; negative ones, it is true, being almost always required in addition. In other words, every fact or phenomenon which has a beginning, invariably arises when some certain combination of positive facts exists, provided certain other positive facts do not exist." [1]

"The cause, then, philosophically speaking, is the sum total of the conditions, positive and negative, taken together; the whole of the contingencies of every description, which being realized, the consequent invariably follows." [2]

In this great definition Mr. Mill provides for no effects but events, and for no causes but complexes of things, of collocations, and of history.

"The state of the whole universe at any instant, we believe to be the consequence of its state at the previous instant: insomuch that one who knew all the agents which exist at the present moment, their collocation in space, and all their properties, in other words, the laws of their agency, could predict the whole subsequent history of the universe, at least unless some new volition of a power capable of controlling the universe should supervene." [3]

[1] *Logic*, p. 239. [2] *Ibid.*, p. 241. [3] *Ibid.*, p. 250.

The cause of the heating of the water in Count Rumford's box, then, and the only thing to which a philosopher can give the name of cause, was the immediately previous state of the universe. And what we have learned from the experiment is the invariable and unconditional succession between that state of the universe and the heating of just such a box of water. But since the universe never was before in just that state, and never will be again, it is hard to see that we have learned anything at all. Mr. Mill refuses to recognize any difference in the relations of the different sorts of causes to the event. "All the positive conditions of a phenomenon are alike agents, alike active."[1]

Although it was with the notion of *succession* that Mr. Mill began his definition of cause, yet he did not hold to it with great firmness. He inquires:—

"Does a cause always stand with its effect in the relation of antecedent and consequent? Do we not often say of two simultaneous facts that they are cause and effect—as when we say that fire is the cause of warmth, the sun and moisture the cause of vegetation, and the like? Since a cause does not necessarily perish because its effect has been produced, the two, therefore, do very generally coexist; and there are some appearances, and some common expressions, seeming to imply not only that causes may, but that they must, be contemporaneous with their effects. *Cessante causâ, cessat et effectus*, has been a dogma of the schools: the necessity for the continued existence of the cause in order to the continuance of the effect, seems to have been once a general doctrine among philosophers. Kepler's numerous attempts to account for the motion of the heavenly bodies on mechanical principles, were rendered abortive by his always sup-

[1] *Logic*, p. 243.

posing that the force which set those bodies in motion must continue to operate in order to keep up the motion which it at first produced. Yet there were at all times many familiar instances in open contradiction to this supposed axiom. A *coup de soleil* gives a man a brain fever: will the fever go off as soon as he is moved out of the sunshine? A sword is run through his body: must the sword remain in his body in order that he may continue dead? A ploughshare once made, remains a ploughshare, without any continuance of heating and hammering, and even after the man who heated and hammered it has been gathered to his fathers. On the other hand, the pressure which forces up the mercury in an exhausted tube must be continued in order to sustain it in the tube. This (it may be replied) is because another force is acting without intermission, the force of gravity, which would restore it to its level, unless counterpoised by a force equally constant. But again: a tight bandage causes pain, which pain will sometimes go off as soon as the bandage is removed. The illumination which the sun diffuses over the earth ceases when the sun goes down.

"There is therefore a distinction to be drawn. The conditions which are necessary for the first production of a phenomenon, are occasionally also necessary for its continuance; but more commonly its continuance requires no conditions except negative ones. Most things, once produced, continue as they are, until something changes or destroys them; but some require the permanent presence of the agencies which produced them at first. These may, if we please, be considered as instantaneous phenomena, requiring to be renewed at each instant by the cause by which they were at first generated. Accordingly, the illumination of any given point of space has always been looked upon as an instantaneous fact, which perishes and is perpetually renewed as long as the necessary conditions subsist. If we adopt this language, we are enabled to avoid admitting that the continuance of the cause is ever required to maintain the effect. We may say, it is not required to maintain, but to reproduce the effect, or else to counteract some force tending to destroy it. And this may be a convenient phraseology. But it is only a phraseology. The fact remains that in some cases (though these are a minority) the con-

tinuance of the conditions which produced an effect is necessary to the continuance of the effect.

"As to the ulterior question, whether it is strictly necessary that the cause, or assemblage of conditions, should precede, by ever so short an instant, the production of the effect (a question raised and argued with much ingenuity by a writer from whom we have quoted), we think the inquiry an unimportant one. There certainly are cases in which the effect follows without an interval perceptible to our faculties; and when there is an interval, we cannot tell by how many intermediate lines imperceptible to us that interval may really be filled up. But even granting that an effect may commence simultaneously with its cause, the view I have taken of causation is in no way practically affected. Whether the cause and its effect be necessarily successive or not, causation is still the law of the succession of phenomena. Everything which begins to exist must have a cause; what does not begin to exist does not need a cause; what causation has to account for is the origin of phenomena, and all the successions of phenomena must be resolvable into causation. These are the axioms of our doctrine. If these be granted, we can afford, though I see no necessity for doing so, to drop the words antecedent and consequent as applied to cause and effect. I have no objection to define a cause, the assemblage of phenomena, which occurring, some other phenomenon invariably commences, or has its origin. Whether the effect coincides in point of time with, or immediately follows, the hindmost of its conditions, is immaterial. At all events it does not precede it; and when we are in doubt, between two coexistent phenomena which is cause and which effect, we rightly deem the question solved if we can ascertain which of them preceded the other."[1]

This admission cannot but be regarded as most damaging for the definition. Mr. Mill's confusion here arises from not having discriminated the various senses of the words cause and effect, and from not having distinguished between matter, energy, persons, events,

[1] *Logic*, pp. 247, 248.

states, and historical concatenations which are mere sequences of possibilities. The effects which Mr. Mill finds following their causes are states; the effects which are simultaneous with their causes are events. When a ball is struck, the motion of the bat passes into it; that effect is simultaneous. But the state of motion once begun continues indefinitely; this effect therefore follows its cause, the blow. Strictly speaking, the cause of an event cannot precede that event. Count Rumford existed, it is true, before his experiment; and in that sense the cause preceded the effect. But, when living under the name of Benjamin Thompson in Connecticut, he was in no proper sense the cause of the experiment years later in Munich. He might have been slain in the war of the Revolution and never have gone to Munich at all. He was not really the cause of the experiment until he performed it. Things exist permanently, and of course both precede and follow their effects. Particular events are always simultaneous with their causes, the things that react. States continue indefinitely after the events that introduce them. Events in history precede the events for which they open the way, and of which they are therefore called the causes.

Mr. Mill says: "The law of Causation, the recognition of which is the main pillar of inductive science, is but the familiar truth that invariability of succession is found by observation to obtain between every fact in nature and some other fact which has preceded it." But this language is exceedingly liable to mislead a hasty reader into thinking that Mr. Mill means to say that each particular fact has some other particular fact

as its cause. "It is seldom, if ever, between a consequent and a single antecedent, that this invariable sequence subsists." In truth, the facts between which Mr. Mill asserts invariability of succession are states of the universe. "The cause," he says, "is the sum total of the conditions, positive and negative, taken together; the whole of the contingencies of every description." "The state of the whole universe at any instant, we believe to be the consequence of its state at the previous instant."

Mr. Mill understands his definition to mean that the cause is the sum total of the conditions "immediately, not remotely, preceding the effect." But it is hard to reconcile this interpretation with the explanations which place historical events among the antecedents. If taking mercury and subsequently being exposed to the air are among the conditions of a man's death, the cause cannot be the total of the immediately antecedent conditions. Mr. Mill escapes the difficulty by saying, that remote events are conditions of the conditions; they are not the causes, but the causes of the causes; or rather factors of the causes of factors of the cause.

Mr. Mill felt that there must be something in causation more than mere invariable succession. There must be something which other writers had attempted to express by the term necessity, and for this he selected the word *unconditionalness*. He says: —

"If there be anything which confessedly belongs to the term necessity, it is *unconditionalness*. That which is necessary, that which *must* be, means that which will be, whatever supposition we may make in regard to other things. The succession of day and night evidently is not necessary in this sense. It is conditional

on the occurrence of other antecedents. That which will be followed by a given consequent when, and only when, some third circumstance also exists, is not the cause, even though no case should ever have occurred in which the phenomenon took place without it."[1]

Returning to the definition, we find the cause to be the antecedent or concurrence of antecedents, that is, a complex; but a complex of what? Of conditions, all equally essential. It is the *assemblage* that constitutes the particular cause. When we are told that the consequent must be unconditionally consequent upon the assemblage of these conditions, what is that but to learn that the assemblage of conditions must lack no condition, that is, must be complete? What Mr. Mill wanted to say was that no superfluous circumstance, nothing that does not have some efficiency, must be counted among the conditions. But since, according to his doctrine, the cause, philosophically viewed, is the immediately previous state of the universe, and since inductive science knows nothing about efficiency, this is difficult to avoid.

Let us revert, parenthetically, to the question whether day is the cause of night, and night the cause of day. This question illustrates the necessity of an analysis of terms before beginning to discuss about facts. All light is not day, nor is all darkness night. The darkness in the Mammoth Cave is not night, nor is the illumination of the cave, by the combustion of magnesium, day. A day is that portion of the sun's illumination which is cut off and individualized by two nights. As soon as this is stated, it is seen that night

is the cause of day. At the north pole there is but one day in the year, because there is but one night. But in what sense is night the cause of day? It is not the efficient cause, nor the material cause, nor the conditional cause, but simply the historical cause. The event, an interruption of light by rotation, makes a possibility for a restoration of light by rotation. If one event did not occur, the other could not occur; the occurrence of night is an essential condition of the occurrence of day.

Mr. Mill holds that the actions of the Will are under exactly the same laws of causation as the reactions of matter. He says:—

"The question, whether the law of causality applies in the same strict sense to human actions as to other phenomena, is the celebrated controversy concerning the freedom of the will; which, from at least as far back as the time of Pelagius, has divided both the philosophical and the religious world. The affirmative opinion is commonly called the doctrine of Necessity, as asserting human volitions and actions to be necessary and inevitable. The negative maintains that the will is not determined, like other phenomena, by antecedents, but determines itself; that our volitions are not, properly speaking, the effects of causes, or at least have no causes which they uniformly and implicitly obey.

"I have already made it sufficiently apparent that the former of these opinions is that which I consider the true one; but the misleading terms in which it is often expressed, and the indistinct manner in which it is usually apprehended, have both obstructed its reception, and perverted its influence when received. The metaphysical theory of free will, as held by philosophers (for the practical feeling of it, common in a greater or less degree to all mankind, is in no way inconsistent with the contrary theory), was invented because the supposed alternative of admitting human actions to be *necessary*, was deemed inconsistent with every one's instinctive consciousness, as well as humiliating to the pride and

even degrading to the moral nature of man. Nor do I deny that the doctrine, as sometimes held, is open to these imputations; for the misapprehension in which I shall be able to show that they originate, unfortunately is not confined to the opponents of the doctrine, but participated in by many, perhaps we might say by most of its supporters.

"Correctly conceived, the doctrine called Philosophical Necessity is simply this: that, given the motives which are present to an individual's mind, and given likewise the character and disposition of the individual, the manner in which he will act may be unerringly inferred; that if we knew the person thoroughly, and knew all the inducements which are acting upon him, we could foretell his conduct with as much certainty as we can predict any physical event. This proposition I take to be a mere interpretation of universal experience, a statement in words of what every one is internally convinced of. No one who believed that he knew thoroughly the circumstances of any case, and the characters of the different persons concerned, would hesitate to foretell how all of them would act. Whatever degree of doubt he may in fact feel, arises from the uncertainty whether he really knows the circumstances, or the character of some one or other of the persons, with the degree of accuracy required; but by no means from thinking that if he did know these things, there could be any uncertainty what the conduct would be. Nor does this full assurance conflict in the smallest degree with what is called our feeling of freedom. We do not feel ourselves the less free, because those to whom we are intimately known are well assured how we shall will to act in a particular case. We often, on the contrary, regard the doubt what our conduct will be, as a mark of ignorance of our character, and sometimes even resent it as an imputation. It has never been admitted by the religious philosophers who advocated the free-will doctrine, that we must feel not free because God foreknows our actions. We may be free, and yet another may have reason to be perfectly certain what use we shall make of our freedom. It is not, therefore, the doctrine that our volitions and actions are invariable consequents of our antecedent states of mind, that is either contradicted by our consciousness, or felt to be degrading.

"But the doctrine of causation, when considered as obtaining between our volitions and their antecedents, is almost universally conceived as involving more than this. Many do not believe, and very few practically feel, that there is nothing in causation but invariable, certain, and unconditional sequence. There are few to whom mere constancy of succession appears a sufficiently stringent bond of union for so peculiar a relation as that of cause and effect. Even if the reason repudiates, imagination retains, the feeling of some more intimate connection, of some peculiar tie, or mysterious constraint exercised by the antecedent over the consequent. Now this it is which, considered as applying to the human will, conflicts with our consciousness, and revolts our feelings. We are certain that, in the case of our volitions, there is not this mysterious constraint. We know that we are not compelled, as by a magical spell, to obey any particular motive. We feel, that if we wished to prove that we have the power of resisting the motive we could do so (that wish being, it needs scarcely be observed, a *new antecedent*), and it would be humiliating to our pride, and paralyzing to our desire of excellence, if we thought otherwise. But neither is any such mysterious compulsion now supposed, by the best philosophical authorities, to be exercised by *any* cause over its effect. Those who think that causes draw their effects after them by a mystical tie, are right in believing that the relation between volitions and their antecedents is of another nature. But they should go farther, and admit that this is also true of all other effects and their antecedents. If such a tie is considered to be involved in the word Necessity, the doctrine is not true of human actions; but neither is it then true of inanimate objects. It would be more correct to say that matter is not bound by necessity, than that mind is so." [1]

Mr. Mill escapes "the depressing effect of the fatalist doctrine" by saying that, while we must will as our character is, we can, if we desire, place ourselves in different circumstances, and these will work in us a different character, and then we shall will differently.

[1] *Logic*, pp. 581, 582.

That is, our history having been what it has, we cannot *will* differently from what we do, but we can *wish* to will differently. But this is to suppose the same cause producing simultaneously a will in one direction and a wish in the other direction, — the same fountain sending forth sweet water and bitter. Mr. Mill says that "human actions are never ruled by any one motive with such absolute sway that there is no room for the influence of any other. The causes, therefore, on which an action depends are never uncontrollable." But it is precisely the characteristic of causation in physics that there is never an alternative *unless some will intervenes.* If human actions are never absolutely ruled by one motive, they differ from the reactions of matter, which are absolutely ruled in each case by one cause.

The conviction made by a careful examination of Mr. Mill's doctrine of Causation is, that it lacks in clearness and self-consistency, and that it is an inadequate basis for the whole superstructure of Inductive Logic.

CHAPTER XI.

CANONS FOR ISOLATING FACTS OF CAUSATION.

It is one task of Science, amid the crowd of phenomena, to distinguish between the coexistences and successions which are accidental and those which rest upon real relations. For it is only by such knowledge that man can live among the terrific forces of nature and can make them the servants of his will. There are many groups of phenomena of which it may be known that when one is present, the others are present also. They are permanent coexistences. There are many events of which it may be known that when one has happened, the other or the others will be sure to follow. There is said to be a relation of causation between them. We have already, at great length, discussed the word cause. An event is the reaction of certain substances and energies in a certain collocation. The reaction by which this collocation arose, or any previous reaction in the long line of history, is an historical cause of the event. This total of things, including the collocation, which is their mutual relation in space, and including their history in time, may be called the *Comprehensive* Cause of the event, and also of the things in their states after the event.

Events are the actions of things. But every action is a reaction. This is a primary induction which men were long in making. The law of inertia, that every body remains in its state of rest or motion until acted

upon, is a subordinate generalization: the wider law is that it takes at least two to make, not only a bargain or a quarrel, but anything. This is often what is understood to be meant by the law of causation; and it seems to be regarded as intuitively known. But it is really an induction.

If we can isolate two things so that we are sure that no third is present, and if then an event occurs, we are sure that it is a reaction between those two things. When a bit of glowing iron is lowered into a jar of oxygen and vivid combustion follows, we are sure that the iron and the oxygen are reacting; those two things are the sole material causes of the event. When a feather and a gold coin are supported in an exhausted receiver and then by the turn of a screw are left unsupported, we know that they are free from all particular influences and are reacting with the general mass of things as a whole: the fall therefore is caused by that reaction alone. This general reaction is called gravitation.

It is plain that the presence of a third thing destroys the isolation and leaves us in doubt. The combustion of a bit of iron in common air, where nitrogen is present, could not be known, without investigation, to be a reaction of the iron and oxygen alone. It might be a mutual reaction of all three or a reaction of the iron and the nitrogen. But so crowded is the world with things, and so multitudinous are their reactions, that it is a rare good fortune to be able mechanically to separate a pair or a group of reagents. What cannot be done physically must be done in thought. We must make a mental elimination, or

perhaps a series of eliminations, and thus discover the various reagents that enter into the comprehensive cause of any event that may be in question. These eliminations are made in thought by the process of subtraction.

Canon First.

FOR ISOLATING FACTS OF CAUSATION BY THE TEST OF DIFFERENCE.

In any two instances, the circumstances which are not common are the causes of the events which are not common.

This brief and general language requires explanation. By an instance is meant any group of phenomena which may be under investigation. By a circumstance is meant a substance, an energy, a will, a collocation, or a previous event. Consequently the cause discovered may be the material cause, the energetic cause, the conditional cause, the volitional cause, or the historical cause — the mere occurrence of the possibility of the reaction of the efficient causes. What is discovered is far more likely to be merely one factor of one of these causes than to be the whole of it; therefore, to avoid the tediousness of constantly saying "at least a part of one of the causes," we will adopt the name *Empirical* Cause. The circumstance discovered by this method is what ordinary experience leads unscientific people to speak of as the cause; and this crude use of experience is what is called empiricism.

The validity of this canon is obvious. Since events are the reactions of things, whatever is different in the

events must come from differences in the things, or in their collocations, which afford the possibilities of reaction. But differences in collocation arise through events. Thus the whole of the differences in two groups of phenomena must be accounted for by the things, their collocations, and their history. Let us consider a concrete example. In a dark room some one touches a button, and immediately a brilliant illumination follows. There are here two instances, the room in darkness and the room illuminated. Viewed historically, the difference in circumstances is that the one instance includes the previous event of the touch of the button and the other does not. The touch of the button is therefore the historical cause of the illumination. But leaving out of view the history, it will be found that the two instances differ in the collocation of things. In the one case materials are so disposed that there is no continuous circuit for the electricity and in the other case there is a continuous circuit. Here is found the conditional cause. Further, the two instances differ, in that in one the electricity passes and in the other it does not; hence we discover the energetic cause, which is the electricity. By thus confining the attention successively to the history, the materials, the energy, or the conditions, the several kinds of cause may be elicited.

Under this canon four cases may arise:—

Case 1. On striking the balance between circumstances and events in the two instances, a single circumstance and a single event may be left, not common to both instances. If so, that circumstance is manifestly the empirical cause of that event. If, for

example, into a glass containing some dilute sulphuric acid a few bits of marble be dropped, vigorous ebullition will ensue. The glass containing the acid, as it was before the dropping in of the marble, constitutes one instance; the same glass containing the marble in addition to the acid constitutes the second instance. Historically viewed, the only difference is that the one instance includes the previous event of the dropping in of the bits of marble; this therefore is the historical cause. But viewed materially, the sole difference is in the bits of marble, which were absent at first and afterwards present. The marble is therefore the material cause of the ebullition. But it is only the *empirical* material cause; it is not the comprehensive material cause, for in that the acid is as important a factor as the marble. When there are a number of things present and a new factor is introduced, we cannot tell by a single application of the canon how many of them co-operate with that new factor in a new comprehensive cause.

Case 2. On striking the balance, a group of circumstances and a group of events may be left not common to the two instances. If so, those circumstances are the empirical causes of those events, but which are the causes of which, can be ascertained only by a further application of the canon to simpler instances. For example, Daniel Webster left the paternal farm and, after spending four years in Dartmouth College, graduated as an accomplished orator. The two instances are Webster without education and without eloquence, and Webster after his college education, delivering some eloquent oration. The two instances

differ in the group of circumstances constituting a college education. But this group is very complex, so that, while it is plain that among the circumstances are included the empirical causes of polished eloquence, it is not plain whether any particular circumstance, as the study of the Greek and Roman classics, was in any sense a cause. Indeed, it may have been a hindrance.

Case 3. On striking the balance, the difference may be found to be, that in the first instance there is more of one circumstance and more of one event than in the second instance. This case is but a variety of the first; for an additional quantity is a new circumstance or a new event. For example, a youth ambitious for athletic honors may, by careful training, wonderfully increase his muscular strength. He has always taken some care of his health, and a little natural superiority may be that which awakens his ambition; but with more care comes more power. Here the added care is a new circumstance and the addition of strength is a new event.

Case 4. On striking the balance, the difference may be found to be that in the first instance there is more of several circumstances and more of several events, the kinds remaining unchanged. This is merely a variety of Case 2; for the new quantities are new circumstances and new events. For example, after taking the Bachelor's degree, one may go on another year and take the Master's degree. He will become a more learned person, but we do not know any better than before, which of his studies have contributed to the group of results included in an education.

These four cases may be expressed in symbols as follows:—

$$1.\ \begin{array}{ll} ABC & def \\ BC & ef \\ \hline A & d \end{array} \qquad 2.\ \begin{array}{ll} ABCD & efgh \\ BC & fg \\ \hline A\ D & e\ h \end{array} \qquad 3.\ \begin{array}{ll} AABC & ddef \\ ABC & def \\ \hline A & d \end{array} \qquad 4.\ \begin{array}{ll} AABCDD & efghh \\ ABCD & efgh \\ \hline A\ D & e\ h \end{array}$$

Let capital letters represent circumstances and small letters represent events. On striking the balance in Case 1, the single circumstance *A* and the single event *d* are found not common. Since what is not common in the events must be owing to what is not common in the circumstances, *A* must be the empirical cause of *d*. In Case 2, *A* and *D* are not common among the circumstances, and *e* and *h* are not common among the events. *A* and *D* include, therefore, the causes of *e* and *h;* but which is the cause of which, or whether one is inert and the other is the cause of both events, we cannot say. We must find another instance presenting *A* without *D* before we can make a further isolation. Case 3 gives the same result as Case 1, and Case 4 gives the same result as Case 2.

In the first case, as soon as we find the instance *ABC def*, we know that those circumstances are the causes of those events; for, unless we are sure that there are no other significant circumstances and events, we have not found the instance at all. Just so, as soon as we find the instance *BC ef*, we know that those circumstances are the causes of those events. We make these affirmations on the basis of the primary induction that all of the events in the world are the reactions of things in the collocations which permit those reactions. Therefore we know that *A*, the

circumstance in which the two instances differ, is the empirical cause of *d*, the event in which they differ. But it often happens that we can find no single instance *BC ef*, although we may know from previous observations that *B* is the cause of *e* and that *C* is the cause of *f*. This makes no difference in the reasoning or in the result. However the knowledge that *B* and *C* cause *e* and *f* has been obtained, we make the same use of it; we subtract from the totals in the first instance those circumstances and events whose relations are already known, and the remaining circumstances and events are then known to be mutually related, or we know at least that among the circumstances are the causes of all the events not common. The same remark may be made *mutatis mutandis* of the three other cases.

From the establishment of a single fact of causation we pass easily to a generalization. The primary inductions, that things persist, and that the qualities of things persist, are already made. What a thing causes once, it always causes under the same conditions. Therefore, after isolating a single fact of causation, we are warranted in the secondary induction, that the circumstance, under the same conditions, will always cause the given event.

The test of difference, when two good instances can be found or artificially produced, is quick and decisive. In the experiment of Count Rumford, it was easy to compare the apparatus when the water was cold and when the water was hot. It was easy also to see that the only circumstance in which the two instances differed was the motion of the cylinder. The event,

the heating, was therefore undoubtedly attributable to that circumstance as empirical cause. But it is not always possible to apply this canon, and then our only resource is one far less satisfactory.

Canon Second.

FOR ISOLATING FACTS OF CAUSATION BY THE TEST OF AGREEMENT.

If in two instances the same event occurs, the common circumstances probably include the cause; and the probability rapidly increases with the number and variety of the instances.

The word cause here still means merely empirical cause. Inexact as this test is, it is often our only expedient, and with care it is highly useful. For example, if twice after the imposition of a protective tariff, business is seen to flourish, a slight probability arises that the tariff is the cause of the prosperity. Yet there is a possibility in each case that some other circumstance, as unusual harvests, or discoveries of rich deposits of the precious metals, may have been the cause. Indeed, the only effect of the tariff may have been to diminish somewhat each time the total prosperity. But every instance in which a tariff is accompanied by prosperity rapidly increases the probability of a genetic connection; since otherwise we must suppose the fortuitous occurrence of some other beneficent cause every time Congress happens to be in favor of protection.

The argument from the test of agreement often seems stronger than it is, from our unconsciously blending it with the argument from the test of differ-

ence. In the case of prosperity after the imposition of a tariff, we naturally compare the country as it was before the tariff and as it was soon after, and thus apply the test of difference; but this gives to the argument from agreement an appearance of strength not its own.

It must be observed that, in the canon, the common circumstances are said simply to *include*, not necessarily all to *be*, the cause. The ashes of seaweeds were long known to possess valuable medicinal powers. The use of them in certain diseases was followed by beneficial effects. But it was not known which of the ingredients was efficient or whether all were efficient; all were common circumstances, but some might be always inert, and some might even be obstructive. Later it was discovered that the useful substance was nothing but iodine; the other things were better away.

As an illustration of how the test of agreement may be applied, with some admixture of the test of difference, we will quote an eloquent passage from Schiller's *Æsthetical Essays:* —

"It is certainly a matter entitled to reflection that, at almost all the periods of history when art flourished and taste held sway, humanity is found in a state of decline; nor can a single instance be cited of the union of a large diffusion of æsthetic culture with political liberty and social virtue, of fine manners associated with good morals, and of politeness fraternizing with truth and loyalty of character and life. As long as Athens and Sparta preserved their independence, and as long as their institutions were based on respect for the laws, taste did not reach its maturity, art remained in its infancy, and beauty was far from exercising her empire over minds. No doubt, poetry had already taken a sublime flight, but it was on the wings of genius, and we know

that genius borders very closely on savage coarseness, that it is a light which shines readily in the midst of darkness, and which, therefore, often argues against, rather than in favor of, the taste of the time. When the golden age of art appears under Pericles and Alexander, and the sway of taste becomes more general, strength and liberty have abandoned Greece; eloquence corrupts the truth, wisdom offends it on the lips of Socrates, and virtue in the life of Phocion. It is well known that the Romans had to exhaust their energies in civil wars, and, corrupted by Oriental luxury, to bow their heads under the yoke of a foreign despot, before Grecian art triumphed over the stiffness of their character. The same was the case with the Arabs: civilization only dawned upon them when the vigor of their military spirit became softened under the Abbassides. Art did not appear in modern Italy till the glorious Lombard league was dissolved, Florence submitting to the Medici, and all those brave cities gave up the spirit of independence for an inglorious resignation. It is almost superfluous to call to mind the example of modern nations, with whom refinement has increased in direct proportion to the decline of their liberties. Wherever we direct our eyes in past times, we see taste and freedom mutually avoiding each other. Everywhere we see that the beautiful only founds its sway on the ruins of heroic virtues."[1]

Under this canon three cases may arise, represented by symbols as follows:—

$$1.\ \begin{array}{ll} ABC & def \\ \underline{ADE} & \underline{dgh} \\ A & d \end{array} \qquad 2.\ \begin{array}{ll} ABC & def \\ \underline{ABE} & \underline{deg} \\ AB & de \end{array} \qquad 3.\ \begin{array}{ll} ABC & def \\ \underline{AFG} & \underline{deh} \\ A & de \end{array}$$

In the first case there is one common event and one common circumstance. In the second case there is a group of common events and a group of common circumstances. In the third case there is a single common circumstance but a group of common events.

This third case suggests a remark, which should be made also regarding the others. A serious element of

[1] Bohn's Trans., p. 55.

uncertainty weakens the test of agreement, and that is what is called the *Plurality of Causes.* What is apparently the same event may be caused by different things. Light may be made by electricity or by combustion. The canon asserts no more than that the common circumstances probably include the cause. Even in Case 1, *A*, the only common circumstance, may not be the cause of *d*, the only common event; for *B* may be the cause of *d* in the first instance and *D* may be the cause of *d* in the second. *A* may be wholly inert in both instances. It is only when a number of instances have been observed that confidence finds much basis. Ebullition may occur in hydrochloric acid, and yet all the common circumstances may be irrelevant, for marble may be the cause in one instance and zinc may be the cause in the second. In Case 3, *A* may be the cause of *d* and some other circumstance may each time cause *e*.

CHAPTER XII.

MR. MILL'S FOUR EXPERIMENTAL METHODS.

To Mr. Mill is due the credit of first distinctly formulating and elaborately discussing the methods of isolating facts of causation. His treatment of the subject has powerfully influenced all subsequent writers, and his terminology has entered into the general vocabulary of philosophy. It is, therefore, necessary for the student to understand these, if he would understand the current literature of inductive logic.

Mr. Mill treats of the tests which we have discussed in the last chapter, under the heading, "The Four Experimental Methods." He recognizes, indeed, that fundamentally there are but two, and says:—

> "The simplest and most obvious modes of singling out from among the circumstances which precede or follow a phenomenon, those with which it is really connected by an invariable law, are two in number. One is, by comparing together different instances in which the phenomenon occurs. The other is, by comparing instances in which the phenomenon does occur, with instances in other respects similar in which it does not. These two methods may respectively be denominated the Method of Agreement and the Method of Difference."[1]

For the application of these methods Mr. Mill proceeds to formulate five canons, as follows:—

[1] *Logic*, p. 278.

First Canon.

For the Method of Agreement.

If two or more instances of the phenomenon under investigation have only one circumstance in common, the circumstance in which alone all the instances agree, is the cause (or effect) of the given phenomenon.

Second Canon.

For the Method of Difference.

If an instance in which the phenomenon under investigation occurs, and an instance in which it does not occur, have every circumstance in common save one, that one occurring only in the former; the circumstance in which alone the two instances differ, is the effect, or the cause, or an indispensable part of the cause, of the phenomenon.

Third Canon.

For the Joint Method of Agreement and Difference; or the Indirect Method of Difference.

If two or more instances in which the phenomenon occurs have only one circumstance in common, while two or more instances in which it does not occur have nothing in common save the absence of that circumstance; the circumstance in which alone the two sets of instances differ, is the effect, or cause, or an indispensable part of the cause, of the phenomenon.

Fourth Canon.

For the Method of Residues.

Subduct from any phenomenon such part as is known by previous inductions to be the effect of certain antecedents, and the residue of the phenomenon is the effect of the remaining antecedents.

FIFTH CANON.

For the Method of Concomitant Variations.

Whatever phenomenon varies in any manner whenever another phenomenon varies in some particular manner, is either a cause or an effect of that phenomenon, or is connected with it through some fact of causation.

Upon these methods we remark :—

1. The name "The Four Experimental Methods" is of doubtful propriety. The methods are confessedly in principle but two ; and the canons are five. But Mr. Mill fixed upon the number four because he did not regard the method of Residues as strictly inductive. The method of Residues provides for those instances of the application of the method of Difference which we have discussed under Case 1 of our Canon 1, on page 98, in which, instead of subtracting a single instance, we subtract the sum of several instances, in order to make the isolation. The fact that in such cases the subtrahend is composite, made by an addition of simpler instances, leads Mr. Mill to formulate a special canon and to declare it deductive. He is not always of the same mind regarding the method of Residues ; since he says, "By previous *inductions* we have ascertained the causes of some of these effects,"[1] meaning those which are added together to make the compound subtrahend ; but he says later, "It concludes not from a comparison of instances, but from the comparison of an instance with the result of a previous *deduction*."[2]

[1] *Logic*, p. 284. [2] *Ibid.*, p. 613.

The method of Residues and the method of Difference are, however, identical in principle. The rare word "subduct," which Mr. Mill employs, means only "take the difference," and a "residue" is nothing but a "difference." The single step of addition cannot make the difference between induction and deduction. Mr. Mill says, "The Method of Residues is in truth a peculiar modification of the Method of Difference," and again, "The Method of Residues, as we have seen, is not independent of deduction; though, as it also requires specific experience, it may, without impropriety, be included among methods of direct observation and experiment." This remark implies that Mr. Mill regarded the other methods as entirely independent of deduction. Still he says of the two fundamental methods, "Both are methods of elimination." But elimination is a purely deductive process. Mr. Mill did not see that deductive logic covers the whole field of induction, that his methods only served to isolate single facts, and that he then combined those facts, directly in making a primary induction, or in a syllogism with some primary induction already made, to get some general truth as a secondary induction. He has told us these things in detached portions with great clearness, but he never put them together. Mr. Mill seems to think that his methods give us general truths immediately. But facts isolated by these methods have no more inductive significance than other single facts which need no artificial isolation.

In attempting to use the test of difference, we may discover that we have not accurately stated our instances. For example, we may think that we have

observed the two instances *BC def* and *BC ef.* But upon comparison it appears that while the causes observed in both instances are the same, there is an effect in one which is not in the other. This shows that we must have overlooked a cause, and puts us upon a search for it. Mr. Mill sometimes seems to regard this correction of instances as a use of the method of residues. He quotes with approval the language of Whewell, "Many of the new elements of chemistry have been detected in the investigation of residual phenomena. Thus Arfwedson discovered lithia by perceiving an excess of weight in the sulphate produced from a small portion of what he considered as magnesia present in a mineral he had analyzed." But this correction of instances is just as likely to occur in using the simple method of difference as in using the method of residues. There is no necessary connection between the correction of instances and the use of a compound subtrahend, which is the characteristic of the method of residues.

The term "experimental" is even less defensible than the number four. For Mr. Mill says: "Of these methods, that of Difference is more particularly a method of experiment; while that of Agreement is more especially the resource employed where experiment is impossible." If it is employed especially where experiment is impossible, some name should be found more appropriate than "experimental."

2. Mr. Mill does not seem aware of the vagueness of the terms and results of his canons. In his chapter on the Law of Causation, he says, "The cause then, philosophically speaking, is the sum total of the condi-

tions positive and negative taken together, the whole of the contingencies of every description, which being realized, the consequent invariably follows." But the methods never isolate a cause in this sense; it is only the empirical cause — some single factor or group of factors. It is, therefore, superfluous to say in the second and third canons "the cause or an indispensable part of the cause."

Mr. Mill regarded *succession* as essential in the notion of causation, and, illustrating the methods by letters of the alphabet, he says, "We shall denote antecedents by large letters of the alphabet, and the consequents corresponding to them by the small." Yet in only one of the canons does he make any reference to sequence. Indeed, he makes them so general that the conclusion may be that the "circumstance" is either the cause or the effect of the phenomenon. This failure to hold fast the idea of sequence leads to curious results. Take the following illustration of the method of agreement: —

> "For example, let the effect *a* be crystallization. We compare instances in which bodies are known to assume crystalline structure, but which have no other point of agreement; and we find them to have one, and as far as we can observe, only one, antecedent in common: the deposition of a solid matter from a liquid state, either a state of fusion or of solution. We conclude therefore, that the solidification of a substance from a liquid state is an invariable antecedent of its crystallization." [1]

It is impossible here to detect any succession. A substance does not first solidify, and then crystallize. What has been discovered, if anything, is not a fact of succession, but one of coexistence.

[1] *Logic*, p. 279.

But in what sense is solidification the cause of crystallization? It is not the material cause; the sugar, alum, or other substance is the material cause. It is not the energetic cause; that is some peculiar kind of cohesion. It is not the historical cause; for the event solidification does not precede the event crystallization. Solidification is not the "unconditional, invariable antecedent" of crystallization, for many substances solidify without crystallizing. All that the investigation has shown is, that if materials take the forms of *regular* solids, they assume regularity *when* they assume solidity. We have discovered not a noun or a verb, but an adverb; the time of solidifying is the time of regularly solidifying.

Mr. Mill seems never to have considered whether, in a sentence, "the cause" is the noun or the verb or some other part of speech. If "Cain killed Abel," was Cain the cause of Abel's death, or was the "killing" the cause? Was it the *arrival* of Blücher at Waterloo that caused the defeat of Napoleon, or was it Blücher himself?

3. Mr. Mill's joint method of Agreement and Difference is wholly an illusion. There is no such method known to science. The discovery of several instances agreeing in nothing has no probative force whatever. If twice after eating lobster I have been ill, the belief that the lobster was the cause of the illness receives no particle of support from the facts that a concave lens disperses light, and that the Turks captured Constantinople.

Dr. Fowler saw that Mr. Mill's statement was defective, and added the condition that the negative instances

must be "within the same department of investigation," that is, they must be good enough for use according to the single method of difference. It is, indeed, often possible to prove a fact independently, both by the test of agreement and by the test of difference; but the combination of these two independently sufficient proofs is not at all what Mr. Mill means by his joint method. In the observations upon the cause of dew, which Mr. Mill and Dr. Fowler use as an illustration of the double method, it was first shown, by a primary induction, that all bodies upon which dew is deposited agree either in losing heat rapidly or in conducting it slowly, that is they have a lower temperature than the air; then the universal negative was admitted, that dew is never found on any other bodies; and then it was inferred that the property of being cooler than the surrounding air was the sole cause of dew. It is obvious that this was something very different from finding two instances of agreement and two instances agreeing in nothing. Mr. Mill says:—

"It thus appears that the instances in which much dew is deposited, which are very various, agree in this, and, so far as we are able to observe, in this only, that they either radiate heat rapidly or conduct it slowly: qualities between which there is no other circumstance of agreement than that by virtue of either, the body tends to lose heat from the surface more rapidly than it can be restored from within. The instances, on the contrary, in which no dew, or but a small quantity of it, is formed, and which are also extremely various, agree (as far as we can observe) in nothing except in *not* having this same property. We seem, therefore, to have detected the characteristic difference between the substances on which dew is produced and those on which it is

not produced. And thus have been realized the requisitions of what we have termed the Indirect Method of Difference, or the Joint Method of Agreement and Difference."[1]

Here several things are confused. The pure method of difference was employed in showing that bodies with dew differed from those without dew simply in being colder than the air. An exhaustive examination established the general negative that dew occurs nowhere else; but this proves, not that coldness is the cause of dew, but that there is no other cause. Suppose that the question had been of heating caused by friction. Two cases agreeing only in the circumstance friction, and in the event heating, would meet the requirements of the first part of the canon; but we cannot prove the universal negative that heating never occurs without friction, and it is inconceivable that any confirmation could be found in the properties of lenses, or the fall of Constantinople.

Dr. Fowler added to Mr. Mill's canon the words: "Moreover (supposing the requirements of the Method to be rigorously fulfilled), the circumstance proved by the method to be the cause is the *only* cause of the phenomenon." He does not tell us how the requirement of finding "two or more instances from which the phenomenon is absent" can be rigorously fulfilled, but a little reflection will show that it is by proving a *universal* negative; this, certainly, is *rigor* in finding "two or more" negative instances.

4. The Method of Concomitant Variations, which corresponds to our Cases 3 and 4 under Canon 1, is used upon some very interesting facts, but logically

[1] *Logic*, p. 299.

has no distinctness from the ordinary method of difference. Nor does the language need to be so elastic. The cases in which the consequent seems to decrease when the antecedent increases are only verbally different from those in which both increase together. All can be stated in terms of increase. For instance, instead of saying "the more heat the less condensation," we may say "the more expansion." Each pair of instances of concomitant variation affords a complete opportunity for the regular application of the test of difference, and the other pairs of cases, which are innumerable, simply enable us to proceed at once to a primary induction.

5. Mr. Mill seems to have exaggerated, with paternal partiality, the importance of these methods, which he had formulated and named and presented to the philosophical world. He says:—

> "The four methods which it has now been attempted to describe, are the only possible modes of experimental inquiry—of direct induction *a posteriori*, as distinguished from deduction; at least I know not, nor am able to imagine any others. And even of these, the Method of Residues, as we have seen, is not independent of deduction; though, as it also requires specific experience, it may, without impropriety, be included among methods of direct observation and experiment. These then, with such assistance as can be obtained from deduction, compose the available resources of the human mind for ascertaining the laws of the succession of phenomena."[1]

According to this, the whole of Induction is concerned with facts of causation; no place is reserved for facts of coexistence or of likeness, or for the inductions built upon them. Nor, indeed, is any explicit provision

[1] *Logic*, p. 291.

made for constructing inductions of *any* kind out of facts. But the facts isolated by these tests must be treated by the mind just like any other data of observation. They are not inductions, but must be generalized into primary inductions, or syllogized into secondary or mixed inductions, if they are to teach us anything. The test of difference gives immediate certainty, each time, regarding one solitary fact of causation. The test of agreement gives, upon the comparison of the first two instances, only a slight presumption of one fact of causation, but this slight probability, upon the comparison of more instances, gradually strengthens into a primary induction of a causal connection in all the instances. It should not be forgotten that no *general* truth can ever be reached in inductive logic except by a primary induction, directly used, or applied as one of the premises of a syllogism. Mr. Mill seems to think that all of the inductive thought of antiquity was simple enumeration, and that the use of the methods is the characteristic of modern science. He speaks of "the ancients with their *inductio per enumerationem simplicem*," somewhat contemptuously. But, of course, the ancients isolated facts, by the methods of agreement and of difference, every hour of their lives ; for they could not make primary inductions without isolating facts. The thinking of the ancients was inexact, but they were not unaccustomed to any fundamental operation of the mind. The characteristic difference between their thinking and ours cannot be, that we have substituted precision in isolating facts, for rashness in generalizing ; the two things are not in the same plane. It is impossible to avoid the belief that what

led Mr. Mill to regard the methods as so much more scientific than *inductio per enumerationem simplicem* was the deductive process, involved in making a secondary induction, which he immediately performed after isolating a single fact of causation, and by which he reached at once a trustworthy generalization.

CHAPTER XIII.

HYPOTHESIS.

WHENEVER we meet with a disconnected fact, the mind instinctively seeks to refer it to some place in the general order. An Hypothesis is a conjecture made to account for some unexplained fact or facts. To account for a fact is to refer it to some uniformity or conjunction of uniformities. To speak then more exactly, an Hypothesis is the reference of a fact to a uniformity or a conjunction of uniformities, before we have evidence enough to feel sure about it. The word *Theory* is often used as synonymous with hypothesis; but it would be better to call the reference an hypothesis *before* we feel sure of its truth and a theory *after* we become sure.

There is no other way to account for facts, except to refer them to uniformities. For the uniformities themselves, no reason can be given. The mind is satisfied with them as finalities. If one asks, Why is that bird black? and is answered, That is a crow and all crows are black, he accepts that answer as sufficient. Or if, being a chemist, he is led to ask, What pigment makes the crow's feathers black? when he finds the presence of a certain substance which is *always* black, he is satisfied. Newton asks why that apple falls, and having generalized that *all* things fall towards each other, is glorified as having *explained* the fall of the apple.

Writers upon inductive logic often please themselves with the notion that they are looking deeper into nature than its uniformities; but this is a delusion. Professor Minto says:—

> "Science aims at reaching 'the causes of things': it tries to penetrate behind observed uniformities to the explanation of them. In fact, as long as a science consists only of observed uniformities, as long as it is in the empirical stage, it is a science only by courtesy. Astronomy was in this stage before the discovery of the Law of Gravitation. Medicine is merely empirical as long as its practice rests upon such generalizations as that Quinine cures ague, without knowing why. It is true that this explanation may consist only in the discovery of a higher or a deeper uniformity, a more recondite law of connection: the point is that these deeper laws are not always open to observation, and that the method of reaching them is not merely observing and recording."[1]

It would be much clearer to say simply that science aims to discover the highest and deepest uniformities, and is not satisfied until it has analyzed the so-called "empirical laws," that is, the uniformities which arise from the co-operation of simpler ones, into their factors. The "Laws of Nature" are merely the uniformities of the resemblances, coexistences, and reactions of things. No uniformity of any kind is open to observation in the sense that it can be known by simply observing and recording, without a mental process. The methods of discovering the deeper uniformities differ in no way from those used in discovering the empirical ones, nor is there any line which marks the boundary between the more and less complex uniformities.

Every person is constantly making hypotheses. Every sensation that comes to the mind challenges an

[1] *Logic*, p. 268.

explanation. It demands to be in some way classified, and refuses to give us rest until disposed of. The ordinary course is to refer the new phenomenon at once to some known uniformity, but often most mistakenly. An amusing illustration occurs in the *Life and Letters of Charles Darwin*:—

"When at Cambridge I used to practice throwing up my gun to my shoulder before a looking-glass to see that I threw it up straight. Another and better plan was to get a friend to wave about a lighted candle, and then to fire at it with a cap on the nipple, and if the aim was accurate the little puff of air would blow out the candle. The explosion of the cap caused a sharp crack, and I was told that the tutor of the college remarked, 'What an extraordinary thing it is, Mr. Darwin seems to spend hours in cracking a horse-whip in his room, for I often hear the crack when I pass under his window.'" [1]

The tutor formed an hypothesis; he referred the sound which he heard to the uniformity which, among those that he knew, it most resembled.

Since, in the production of any event, a large number of uniformities frequently coincide, most hypotheses are somewhat complex, but their essential nature is the same.

No criterion can be fixed by which it may be decided when the reference of a fact to a uniformity passes from the condition of an hypothesis to that of an induction. When the mind is satisfied that there is proof enough, the hypothesis becomes an induction. This point will be reached much more readily by some minds than by others. Professor Huxley regarded the opinion that modern horses are descended from small

[1] Page 31.

five-toed progenitors as "demonstratively established," while many others still looked upon evolution as a very slenderly supported hypothesis.

An Hypothesis is legitimate: —

1. When it includes all the known facts in the case.

2. When it is the simplest that has been suggested.

3. When the supposed phenomena fall into the lines of known uniformities.

This third requirement is, we believe, what Sir Isaac Newton meant by laying down the rule that the hypothesis must assign a *vera causa*, a true cause. He could not have meant that no *new* cause must be assumed, for the very purpose of hypothesis is to deal with new things. He could not have meant that the cause assumed must be the *real* cause; for that would have been a foolish truism. He must have meant that the assumed uniformity was to be of a kind already known to exist. For example, if an explosion occurs in a flouring mill, we may adopt the hypothesis that it was caused by the fine, floating dust of flour, in sudden combustion. Many substances have the property of explosive combustion; this is a *vera causa*. If flour has this property, it but adds one more in an already established line of uniformity. But should we assume that the explosion was caused by ghosts, this would not be in line with what is known to happen in other cases; we should have not only a new cause, but a new kind of cause.

An hypothesis is *illegitimate* when it violates any one of the foregoing rules. It is *gratuitous* when it violates the second rule, or when there are no unexplained facts to start with. It is irrational to make a

gratuitous hypothesis, for inductive science cannot let go of facts.

Mr. Mill's definition is as follows: —

> "An hypothesis is any supposition which we make (either without actual evidence, or upon evidence avowedly insufficient), in order to endeavor to deduce from it conclusions in accordance with facts which are known to be real; under the idea that, if the conclusions to which the hypothesis leads are known truths, the hypothesis itself either must be, or at least is likely to be, true." [1]

Mr. Mill lays it down as a condition of a genuinely scientific hypothesis, "that it be not destined always to remain an hypothesis, but be certain to be either proved or disproved by that comparison with observed facts which is termed verification." This condition we cannot accept; the mind is impelled to account for the phenomena about it in the simplest and most harmonious manner possible, and the question of expectation for the future is wholly irrelevant. The hypothesis that a certain ship that sailed away from port and never was heard from again, ran into an iceberg, is perfectly legitimate, if it accounts for all the facts, is the simplest suggested, and is in line with what happens in that part of the ocean. Whether we expect to find hereafter some of the wreckage, it is not necessary to consider.

The right use of hypothesis was well illustrated in the discovery of the planet Neptune. For some time it had been observed, that the orbit of the planet Uranus was subject to an amount of perturbation which could not be accounted for from the influence of known planets.

[1] *Logic*, p. 349.

"Of the various hypotheses formed to account for it [the perturbation], during the progress of its development, none seemed to have any degree of rational probability but that of the existence of an exterior, and hitherto undiscovered, planet, disturbing, according to the received laws of planetary disturbance, the motion of Uranus by its attraction, or rather superposing its disturbance on those produced by Jupiter and Saturn, the other two of the old planets which exercise any sensible disturbing action on that planet. Accordingly, this was the explanation which naturally, and almost of necessity, suggested itself to those conversant with the planetary perturbations who considered the subject with any degree of attention. The idea, however, of setting out from the observed anomalous deviations, and employing them as data to ascertain the distance and situation of the unknown body, or, in other words, to resolve the inverse problem of perturbations, 'given the disturbances, to find the orbit and the place in that orbit of the disturbing planet,' appears to have occurred only to two mathematicians, Mr. Adams in England and M. Leverrier in France, with sufficient distinctness and hopefulness of success to induce them to attempt its solution. Both succeeded, and their solutions, arrived at with perfect independence, and by each in entire ignorance of the other's attempt, were found to agree in a surprising manner when the nature and difficulty of the problem is considered; the calculations of M. Leverrier assigning for the heliocentric longitude of the disturbing planet for the 23rd Sept., 1846, 326° 0′, and those of Mr. Adams (brought to the same date) 329° 19′, differing only 3° 19′; the plane of its orbit deviating very slightly, if at all, from that of the ecliptic.

"On the day above mentioned — a day forever memorable in the annals of Astronomy — Dr. Galle, one of the astronomers of the Royal Observatory at Berlin, received a letter from M. Leverrier, announcing to him the result he had arrived at, and requesting him to look for the disturbing planet in or near the place assigned by his calculation. He did so, and on that very night actually found it. A star of the eighth magnitude was seen by him and by M. Encke in a situation where no star was marked as existing in Dr. Bremiker's chart, then recently published by the Berlin Academy. The next night it was found to have moved

from its place, and was therefore assuredly a planet. Subsequent observations and calculations have fully demonstrated this planet, to which the name of Neptune has been assigned, to be really that body to whose disturbing attraction, according to the Newtonian law of gravity, the observed anomalies in the motion of Uranus were owing.[1]

The manner in which scientific men construct theories may be illustrated by Darwin's conjectures as to the formation of coral islands: —

"*Subsidence Theory of Darwin.* — This theory explains not only atolls, but also barriers, and connects both in a satisfactory manner with fringing reefs. It supposes that the sea-bottom, where atolls and barriers occur, has been for ages subsiding, but at a rate not greater than the upward building of the coral-ground; that every reef commences as a fringing reef, but, in the progress of subsidence, was converted first into a barrier and finally into an atoll. For, as the volcanic island went down, the corals would build upward on the same spot; and as the island would become smaller and smaller, and the corals would grow faster on the outer side of the reef, where they are exposed to the breakers, it is evident that the reef would become separated from the island by a ship-channel, and thus become a barrier. Finally, when the island disappears entirely, the reef, still building upward, would become an atoll. . . . It is seen that the corals do not build a vertical wall, and therefore that the atoll is always smaller than the coast-line of the original island. Consequently, if the subsidence continues, a typical atoll is changed into a small, closed lagoon, and, finally, into a lagoonless island. These, therefore, indicate the deepest subsidence.

"*Evidences.* — 1. This theory accounts for all the more obvious phenomena of atolls, such as their irregular circular form, their size, the steepness of their outer slopes, etc. 2. Every stage of gradation between the fringing reef on the one hand, and the atoll on the other, has been traced by Dana, strongly suggesting that

[1] Herschel's *Outlines of Astronomy*, fourth ed., §§ 767, 768, quoted by Fowler, *Inductive Logic*, pp. 177, 178.

they are all different stages of development of the same thing. We have in the Pacific some high islands, which are surrounded by a pure fringing reef; others in which the reef is a fringe on one side and a barrier on the other; others in which the barrier is one mile, two miles, five miles, ten miles, twenty, or thirty miles distant; others which are called atolls, but the point of the original volcanic island is still visible in the middle of the lagoon; others which are perfect atolls, but, by sounding, the head of the drowned volcanic island is still detectable. The next step in the series is the perfect atoll, then the small atoll, and, finally, the lagoonless coral island. These last kinds show that the original island has gone down deeply. 3. By grappling-hooks *dead* coral-trees have been broken off and brought up from the ground where they once grew, now far below the limiting depth of coral growth. The evidence of subsidence in this case is of the same kind and force as that derived from submerged forest-ground. The corals have been carried below their depth and drowned. 4. The remarkable distribution of the various kinds of reefs brought to light by Dana is satisfactorily explained by this theory, and therefore is an argument in its favor. In the middle of the atoll region of the Pacific there is a *blank area*, 2000 miles long and 1000 or more miles wide, where there are no islands. Next about this is an area in which *small atolls* predominate; about this again the region of ordinary atolls; beyond this the region mostly of barriers, and finally of fringes. Now, by this theory this distribution is thus explained: The sea-bottom in the blank area has gone down so fast that the corals have not been able to keep pace, and have therefore been drowned, and left no monument of their existence. In the next region the corals have been able to keep within living distance of the surface, but the original islands have not only disappeared, but gone down to great depths. In the next the original high islands have disappeared, but not gone down so deep; in the next they have sunk only to the middle. The fringing reefs stand on the margin of the sinking area. Outside of this again there is in some places even evidence of upheaval instead of subsidence. Raised beaches in the form of fringing-reef rocks are found clinging to the sides of high islands many feet above the present sea-level. 5. In some places this

subsidence seems to be still in progress. On certain coral islands sacred structures of stone made by the natives are now standing in water, and the paths worn by the feet of devotees are now passages for canoes (Dana)."

"*Murray's Theory.* — Recently serious doubts have been cast on Darwin's subsidence theory, at least as a universal explanation of barriers and atolls. Mr. Murray, from his observations during the voyage of the *Challenger*, believes that barriers and atolls may be explained without subsidence of the sea-floor. An outline of his views may be thus stated: (1) Submarine banks formed in any way, either (*a*) built up by accumulating shells of successive generations of marine animals, until within the reach of coral growth; or (*b*) by volcanic cinder cones cut down by the waves so as to form suitable banks. (2) The banks taken possession of by corals are built up to the sea-level. (3) The coral growth is confined, or at least most rapid, on the outer margin, because exposed to the action of the sea. Thus arises a ring with blank space within. (4) The action of waves beats these rings into a series of islets. (5) Meanwhile the scouring action of currents and the solvent action of sea-water scoops out the blank area into a more or less deep lagoon. (6) The action of waves breaking the living coral and the reef-rock forms a *débris*-pile or talus, with steep outward slope, on which the corals continue to grow seaward into deep water. Thus the coral ring continues to spread, like a *fairy* ring, by growing seaward in every direction, and dying behind. (7) According to Darwin, atolls grow continually smaller; according to Murray, they grow continually larger.

"Barriers are similarly explained. They commence as fringes, which grow seaward as far as depth will allow. Then the corals die near the shore, and this part is scoured out into a channel. Meanwhile the reef extends seaward on its own talus, and the channel is *pari passu* widened.

"In the present condition of the question it is probable that there are more ways than one in which barriers and atolls may be formed, but Darwin's view seems still to hold its own as a general, though not as a universal theory." [1]

[1] Le Conte's *Geology*, pp. 150–153.

The formation of wise hypotheses is the most important step in the progress of science. It is simply suspecting the lines of nature's uniformity from slight hints. The fundamental preparation for it is intimate familiarity with the general system of things, so far as discovered. Helmholtz has well stated the case in the following passages. It will be observed that instead of "foreknowledge" it would have been better to use a more general word. Induction has as much to do with the past, the distant, and the unobservable present, as it has to do with the future. It deals with all of these not as past, present, and future, but as unseen parts of the *existing* order; it is able to reason about them only as parts of that order.

"In order to acquire this foreknowledge of what is coming, but of what has not been settled by observations, no other method is possible than that of endeavoring to arrive at the laws of facts by observations; and we can only learn them by induction, by the careful selection, collation, and observation of those cases which fall under the law. When we fancy that we have arrived at a law, the business of deduction commences. It is then our duty to develop the consequences of our law as completely as may be, but in the first place only to apply to them the test of experience, so far as they can be tested, and then decide by this test whether the law holds, and to what extent. This is a test which really never ceases. The true natural philosopher reflects at each new phenomenon, whether the best established laws of the best known forces may not experience a change; it can, of course, only be a question of a change which does not contradict the whole store of our previously collected experiences. It never thus attains unconditional truth, but such a high degree of probability that it is practically equal to certainty."[1]

"In speaking against the empty manufacture of hypotheses, do not by any means suppose that I wish to diminish the real value

[1] Helmholtz, *Popular Scientific Lectures*, p. 226.

of original thoughts. The first discovery of a new law, is the discovery of a similarity which has hitherto been concealed in the course of natural processes. It is a manifestation of that which our forefathers in a serious sense described as 'wit'; it is of the same quality as the highest performances of artistic perception in the discovery of new types of expression. It is something which cannot be forced, and which cannot be acquired by any known method." [1]

Dr. Whewell has discussed at length the cause of the failure of the Greek physical philosophy. From this discussion we will make a few extracts:—

"The cause of the failure of so many attempts of the Greeks to construct physical science is so important, that we must endeavor to bring it into view here; though the full development of such subjects belongs rather to the Philosophy of Induction.

"The cause of failure was *not the neglect of facts*. It is often said that the Greeks disregarded experience, and spun their philosophy out of their own thoughts alone; and this is supposed by many to be their essential error. It is, no doubt, true that the disregard of experience is a phrase which may be so interpreted as to express almost any defect of philosophical method; since coincidence with experience is requisite to the truth of all theory. But if we fix a more precise sense on our terms, I conceive it may be shown that the Greek philosophy did, in its opinions, recognize the necessity and paramount value of observations; did, in its origin, proceed upon observed facts, and did employ itself to no small extent in classifying and arranging phenomena.

"'The way must be the same,' says Aristotle, in speaking of the rules of reasoning, 'with respect to philosophy, as it is with respect to any art or science whatever; we must collect the facts and the things to which the facts happen, in each subject, and provide as large a supply of these as possible.'

"We come back, again, therefore, to the question, What was the radical and fatal defect in the physical speculations of the Greek philosophical schools?

[1] Helmholtz, *Popular Scientific Lectures*, p. 227.

"To this I answer: The defect was, that though they had in their possession Facts and Ideas, *the Ideas were not distinct and appropriate to the facts.*

"The peculiar characteristics of scientific ideas, which I have endeavored to express by speaking of them as *distinct* and *appropriate to the facts*, must be more fully and formally set forth when we come to the philosophy of the subject. In the meantime, the reader will probably have no difficulty in conceiving that for each class of Facts there is some special set of Ideas, by means of which the facts can be included in general scientific truths; and that these Ideas which may thus be termed *appropriate*, must be possessed with entire distinctness and clearness, in order that they may be successfully applied. It was the want of Ideas having this reference to material phenomena which rendered the ancient philosophers, with very few exceptions, helpless and unsuccessful speculators on physical subjects."[1]

The point which Dr. Whewell makes here seems to us exactly provided for in the third rule given above for legitimate hypotheses. The Greeks failed, because their conjectures were not in the lines of known uniformities of nature. They sought the causes of phenomena in abstract and general conceptions.

Important as is the function of hypotheses, it may yet be exaggerated. Thus, Professor Davis says:—

"It is equally obvious that all experimental observation is likewise dependent on supposition. A mere trial of possible combinations to see what will come of them, without the further suggestions of a suggested supposition, can elicit nothing, save by chance."[2]

But it is plain that a chemist may take the contents of the stomach of a murdered man, and may test successively for arsenic, strychnine, and other poisons, with-

[1] Whewell's *History of the Inductive Sciences*, vol. i, pp. 83, 87.

[2] *Inductive Logic*, p. 159.

out any hypothesis whatever ; and that he will reach the truth just as quickly without an hypothesis as with one. In every chemical laboratory, students are taught a regular system of tests, by which any questionable substance may be quickly identified without an hypothesis. Indeed, the tendency of science is to dispense with hypotheses as guides in research, to cease asking nature "leading questions," and to carry investigations forward on plans that permit the facts to speak for themselves. It is a waste of time to frame an hypothesis before all of the facts which can be ascertained are in hand.

Dr. Fowler says:—

> "Even though a hypothesis may ultimately be discovered to be false, it may be of great service in pointing the way to a truer theory. Thus, as already remarked, the circular theory of planetary motion, and the supplementary theory of epicycles and eccentrics, undoubtedly contributed to the formation of the hypothesis which was eventually proved true. Kepler himself tried no less than nineteen different hypotheses before he hit upon the right one, and his ultimate success was, doubtless, in no slight degree due to his unsuccessful efforts. There is hardly any branch of science in which it might not be affirmed that without a number of false guesses true theories could never have been attained."[1]

The service which a false hypothesis renders is rather moral then intellectual. The belief that one has found a clue to the truth tends to keep up courage, and courage is necessary to persistent work upon the facts. But the false hypothesis, in itself considered, is purely a disadvantage and waste of time ; it is, like every false scent, a diversion from the right path. In searching

[1] *Inductive Logic*, p. 99.

for something, we are not likely to strike upon it at the first effort ; and therefore our false guesses may be said to be necessary to our success. Where there are a number of equal possibilities, one must begin somewhere, and go on proving negatives, until the right one is reached. If a paper is in the desk, and there are four drawers, one as likely to contain it as another, the successive hypotheses that it is in the first, second, and third, will keep us looking, and when they are exploded we shall know that it is in the fourth. There is no absolute way to escape the tedium of testing wrong hypotheses, but we are fortunate in proportion to the fewness of those that we make, and the best rule is to delay in making any conjecture as long as possible. Grant's disastrous charge at Cold Harbor was necessary to his final victory over Lee, simply in showing that if he was ever to conquer, it must be in some other way ; this is all of the intellectual value that can ever attach to a false hypothesis.

CHAPTER XIV.

INDUCTIVE ARGUMENTS.

HAVING considered the elementary steps of inductive investigation, we now advance to the construction of inductive arguments.

A very common form of argument is that from *Analogy*. Such an argument is based upon a primary induction of a uniformity of resemblances. Having observed a certain object to have, in many respects, the property x, we come to think that we are upon the line of one of its uniformities, and that it will be found to have, in all respects, the property x. But x may stand for resemblance to some other object.

As Bishop Butler has said:—

"Probable evidence is essentially distinguished from demonstrative by this, that it admits of degrees, and of all variety of them, from the highest moral certainty to the very lowest presumption. We cannot, indeed, say a thing is probably true upon one very slight presumption for it; because, as there may be probabilities on both sides of the question, there may be some against it; and though there be not, yet a slight presumption does not beget that degree of conviction which is implied in saying that a thing is probably true. But that the slightest possible presumption is of the nature of a probability, appears from hence, that such low presumption, often repeated, will amount even to moral certainty. Thus, a man's having observed the ebb and flow of the tide to-day, affords some sort of presumption, though the lowest imaginable, that it may happen again to-morrow; but the observation of this event for so many days and months, and ages together, as it has been observed by mankind, gives us a full assurance that it will." [1]

[1] Introduction to the *Analogy of Religion*.

Now a uniformity of resemblances is just like any other line of uniformity, and the argument from it is the same. If I have often found a substance white, I begin to expect to find it of that color next time ; and if I have found it to resemble another substance in many respects, I expect to find more resemblances. An argument from Analogy, therefore, does not differ in any way from an argument based upon any other primary induction. A primary induction may be made that the peach trees of a certain region yield a crop three seasons out of four ; and this becomes the basis of expectation. Just so the induction may be made that two objects *resemble* each other in three respects out of four (or according to any other ratio), and this will measure the probability of resemblance in any unexamined instance.

The following example of the use of the argument from analogy is taken from the *Scientific Papers of Asa Gray* : —

"The most interesting ideas connected with trees are those suggested by their stability and duration. They far outlast all other living things, and form the familiar and appropriate symbols of long-protracted existence. 'As the days of a tree shall be the days of my people' is one of the most beautiful and striking figures under which a blessing can be conveyed. We are naturally led to inquire, whether there is any absolute limit to their existence. If not destroyed by accident, — that is, by extrinsic causes, of whatever sort, — do trees eventually perish, like ourselves, from old age? It is commonly thought, no doubt, that trees are fully exposed to the inevitable fate of all other living things. The opposite opinion seems to involve a paradox, and to be contradicted by every one's observation. But popular opinion is an unsafe guide ; — the more so in this case, as our ordinary conceptions on the subject spring from a false analogy, which we have

unconsciously established, between plants and animals. This common analogy might, perhaps, hold good, if the tree were actually formed like the animal, all the parts of which are created at once in their rudimentary state, and soon attain their fullest development, so that the functions are carried on throughout life in the same set of organs. If this were the case with the tree, it would likewise die, sooner or later, of old age, — would perish from causes strictly analogous to those which fix a natural limit to the life of animals. The unavoidable induration and incrustation of its cells and vessels, apart from other causes, would put an early and sure limit to the life of the tree, just as it does in fact terminate the existence of the leaf, the proper emblem of mortality, — which, although it generally lives only a single season, may yet truly be said to die of old age. But, as the leaves are necessarily renewed every year, so also are the other essential organs of the plant. The tree is gradually developed by the successive addition of new parts. It annually renews not only its buds and leaves, but its wood and its roots; everything, indeed, that is concerned in its life and growth. Thus, like the fabled Æson, being restored from the decrepitude of age to the bloom of early youth, — the most recent branchlets being placed, by means of the latest layer of wood, in favorable communication with the newly-formed roots, and these extending at a corresponding rate into fresh soil, —

> Quae quantum vertice ad auras
> Ætherias, tantum radice in Tartara tendit,'

why has not the tree all the conditions of existence in the thousandth that it possessed in the hundredth, or the tenth, year of its age? The old and central part of the trunk may, indeed, decay; but this is of little moment, so long as new layers are regularly formed at the circumference. The tree survives, and it is difficult to show that it is liable to death from old age in any proper sense of the term. Nor do we arrive at a different conclusion when we contemplate the tree under a less familiar but more philosophical aspect, — considering it not as a simple individual, like man or the higher animals, but as an aggregate of many individuals, which, though ordinarily connected with the parent stalk, are capable of

growing by themselves, and, indeed, often do separate spontaneously, and in a variety of ways acquire independent existence. If, then, the tree be, as it undeniably is, a complex being, an aggregate of as many individuals, united in a common trunk, as there are, or have been, buds developed on its surface; and if the component individuals be annually renewed, why should not the aggregate, the *tree*, last indefinitely? To establish a proper analogy, we must not compare the tree with man, but with the coral formations, in which numberless individuals, engrafted and blended on a common base, though capable of living when detached from the mass, conspire to build up those arborescent structures so puzzling to the older naturalists that they were not inappropriately named 'zoöphytes,' or animal-plants. The immense coral-groves, which have thus grown up in tropical seas, have, no doubt, endured for ages; the inner and older parts consisting of the untenanted cells of individuals that have long since perished, while fresh structures are continually produced on the surface. The individuals, indeed, perish, but the aggregate may endure as long as time itself. So with the tree, considered under this point of view. Though the wood in the center of the trunk and large branches — the produce of buds and leaves that have long ago disappeared — may die and decay, yet while new individuals are formed upon the surface with each successive crop of fresh buds, and placed in as favorable communication with the soil and the air as their predecessors, the aggregate tree would appear to have no necessary, no inherent limit to its existence."[1]

The question here is, whether the analogy, the uniformity of resemblance, is between the tree and an individual animal, or between the tree and a community of animals. Most readers will suspect that neither analogy is complete enough to justify the conclusions suggested.

The relation of primary and secondary inductions in constructing an argument is admirably illustrated in

[1] Vol. ii, p. 79.

the famous incident of Robinson Crusoe's discovery of the solitary footprint in the sand. The story runs as follows:—

"It happened one day, about noon, going towards my boat, I was exceedingly surprised with the print of a man's naked foot on the shore, which was very plain to be seen on the sand. I stood like one thunderstruck, or as if I had seen an apparition. I listened, I looked around me, but I could hear nothing nor see anything; I went up to a rising ground to look farther; I went up the shore and down the shore, but it was all one; I could see no other impression but that one."

Crusoe was already in possession of the primary induction, "Impressions of a given form are made only by men." Observation supplied the minor premise, "Here is an impression of the given form." The secondarily inductive conclusion followed, "A man made this."

A more complex illustration may be taken from the writings of the eminent glacialist, Professor G. Frederick Wright:—

"In the summer of 1882, after having the previous year completed, with Professor Lewis, the exploration of the glacial boundary through Pennsylvania, I continued to work through the state of Ohio, and traced the line at length to the Ohio River, near Ripley, about sixty miles above Cincinnati. From this point, for about thirty miles down the river, to the vicinity of New Richmond, the glacial boundary lies upon the north bank of its trough; till, bowlders, and scratched stones being found on the highlands down to the extreme margin on the north side, but being absent from the corresponding highlands on the Kentucky side. Near Point Pleasant, the birth-place of President Grant, the river makes a long bend to the north, continuing in this direction to Cincinnati, and thence westward to North Bend, the home and burial-place of President William Henry Harrison; here it turns

south again, thus forming in Kentucky a peninsula, as it were, pointing to the north, and including the territory of Campbell, Kenton, and Boone counties. Upon examining this district it was found that in places in Campbell county, and over the whole northern and western parts of Boone county, there were true glacial deposits on the highest lands — the elevation near Burlington being five hundred and fifty feet above low-water mark at Cincinnati. In places, large numbers of bowlders of northern origin were found stranded on the very summit-level of the region — *i.e.*, on the divide, between the short streams running north and those running south, and between the Licking and the Ohio River. They were also found south of this secondary divide, seven miles back from the river, and five hundred feet above it (near Florence, Boone county). Several were recognized as belonging to a species of red jasper conglomerate, whose outcropping is well marked on the northern shore of Lake Huron and above the outlet of Lake Superior. These bowlders are very beautiful; and, farther north, where they are more abundant in the fields, are frequently used to adorn the front-yards of residences or even for the construction of public buildings. Some of the citizens of Cleveland, Ohio, have brought large fragments for this purpose from the parent ledges. But here, beside a roadway through the Kentucky hills, were large specimens of this same conglomerate (one bowlder being nearly three feet in diameter), which had been transported by glacial ice fully six hundred miles from their native bed, and left to tell the story not only of their own travels, but of other most interesting events connected with the cause which transported them. These glacial deposits south of the Ohio are such as to make it certain that the front of the continental glacier itself pushed, at some points, seven or eight miles beyond the Ohio River; and it is altogether probable that for a distance of fifty miles (or completely around the eastern, northern, and western sides of the Kentucky peninsula formed by the great bend of the river), the ice came down to the trough of the Ohio, and crossed it so as completely to choke the channel, and form a glacial dam high enough to raise the level of the water five hundred and fifty feet — this being the height of the water-shed to the south. The consequences following are interesting to trace.

"The bottom of the Ohio River at Cincinnati is 447 feet above the sea-level. A dam of 553 feet would raise the water in its rear to a height of 1000 feet above the tide. This would produce a long, narrow lake, of the width of the eroded trough of the Ohio, submerge the site of Pittsburg to a depth of 300 feet, and make slack water up the Monongahela nearly to Grafton, W. Va., and up the Alleghany as far as Oil City. All the tributaries of the Ohio would likewise be filled to this level with the back water. The length of this slack-water lake in the main valley, to its termination up either the Alleghany or the Monongahela, was not far from one thousand miles. The conditions were also peculiar in this, that all the northern tributaries head within the southern margin of the ice-front, which lay at varying distances to the north. Down these northern tributaries there must have poured during the summer months immense torrents of water to strand bowlder-laden icebergs on the summits of such high hills as were lower than the level of the dam."[1]

Let us trace the inductive steps by which the conclusion is reached that there was once a lake in the valley of the Ohio. First there is the primary induction that, "This red jasper conglomerate is original only in Canada." This is proved only by an exhaustive examination in detail of all the rocks *in situ* in the whole region concerned, such examination being continued until the mind of the investigator is satisfied — a point not precisely definable. Next comes the primary induction, "Angular and scratched bowlders like these are the work of glaciers." This is a primary induction made by the test of agreement by observation upon living glaciers. The united observation of geologists over the whole world warrants another primary induction, the universal negative, "No agents but glaciers are making scratched bowlders." Observation

[1] *Ice Age in North America*, p. 326.

gives us the fact, "There are angular and scratched pieces of this jasper conglomerate in Boone county, Kentucky." Next is the secondary induction, "The ice-sheet extended into Boone county." But the mathematical proposition may be affirmed, "An ice-sheet extending from Canada into Boone county would dam the Ohio River." Thus we reach at last the mixed induction, "The Ohio River was once closed by an ice-dam." Again it may be affirmed, "If there was a dam, there was a lake"; which leads to the mixed induction, "There was a lake." The validity of these conclusions depends wholly upon the accuracy of the observations, and the exhaustiveness of the examinations by which the universal negatives are established.

The subject of *Verification* has been so luminously presented by Dr. Fowler that nothing more will be necessary than to quote his remarks :—

"In Deductive Reasoning, especially when it involves elaborate calculations, there is always great danger lest we should have omitted to take into account some particular agency or element, or have miscalculated its effects, or have formed a false estimate of the combined effect of the various agencies or elements in operation. The only remedy against these possible errors, besides the employment of great caution in the conduct of the deductive process itself, is to be found in Verification, a word which, in its stricter sense, appears to be applied to the process of testing, by means of an appeal to facts, the validity of the conclusions already arrived at by a course of deductive reasoning. Thus it had been deductively inferred from the Copernican theory that the planets Venus and Mercury ought to pass through phases, like the moon, and the application of the telescope, by means of which they were actually seen to assume these phases, furnished a triumphant verification of the inference. Every occurrence of an eclipse of the sun or moon or of the transit or occultation of a star, when it

accords with the previous calculations of astronomers, is also an instance of Verification in this the stricter sense of the term. The discovery of the planet Neptune affords an excellent instance of the same kind. But the word is often used in a looser sense and extended to all cases in which an appeal is made to facts, as, for instance, when we perform an experiment in order to test the truth of a hypothesis, or where we employ the Method of Difference in order to supplement the characteristic uncertainty attaching to the employment of the Method of Agreement. Of the process denoted by this looser sense of the word, instances will readily occur to every one. Thus, the diminution in the periods of Encke's comet has been regarded by some astronomers (though, perhaps, erroneously) as a verification of the theory that space is filled with an interstellar medium ; or, to take an instance from a very different class of subjects, the recent breaking up of the slave system in the Southern States of America may be regarded as a verification of the prediction that slave and free institutions could not long coexist under the same political form of government. For an instance of a case in which the Method of Difference is called in to verify a previous employment of the Method of Agreement, I may refer back to the inquiry into the cause of crystallization, already adduced in my discussion of those two methods.

"There is a still wider application of the word Verification, by which it is extended to any corroboration of one mode of proof by means of another. It thus includes a deductive proof adduced in corroboration of an inductive one. The most common instance of this kind of verification is the inclusion of a partial under a more general law, the partial law having been arrived at inductively, and it being subsequently shown that the more general law leads deductively to it. Thus, the phenomena of the Tides had, prior to the epoch of Newton, been partially explained by the inductive method. Newton, by deducing these phenomena from the Law of Universal Gravitation, not only afforded a much more complete explanation, but also furnished the most convincing verification of the results already arrived at. Similarly the laws of falling bodies on the earth's surface, which had already been proved inductively, were, from the time of Newton, brought under the law of universal gravitation, and proved deductively from it. The same was also

the case with Kepler's Laws, when they were proved deductively from the theorem of the central force. This mode of verification is recommended by Mr. Mill, under the name of the Inverse Deductive or Historical Method, as specially applicable to generalizations on society which have been inferred inductively from the study of history or the observation of mankind. These generalizations are subsequently verified by being connected deductively with the general laws of mind or conduct which are furnished by the study of Psychology or Ethology. It is thus shown that the generalizations of history are such as we might have anticipated *a priori* from a general knowledge of human nature, and each branch of the inquiry is made in this manner to afford a striking confirmation of the results arrived at by the other.

"It need hardly be remarked that any verification of one inductive proof by another, or of a deduction by an induction, should conform with the laws of deductive or inductive reasoning as the case may be. Verification is not a distinct mode of proof, but is simply the confirmation of one proof by another, sometimes of a deduction by an induction, sometimes of an induction by a deduction, and, finally, sometimes of one induction or deduction by another. It must also be borne in mind that the term is not infrequently employed to designate simply the confirmation of a hypothesis by an appeal to facts."[1]

In trials at law the State sets itself to ascertain the truth regarding certain alleged facts. The inquiry is a strictly inductive one, and every part of the procedure must, if just, illustrate the sound principles of this branch of logic. Since the community cannot act directly, special officers are appointed to represent it. Everything is done by exact rules, which, although they seem to the thoughtless to be arbitrary, have been established because experience has shown that, by the observance of them, truth will be, in the largest number of cases, arrived at.

[1] *Inductive Logic*, pp. 249–253.

Any criminal charge against a man is in the first place submitted to a Grand Jury. This body passes upon the question whether the hypothesis that the accused committed the offense charged is legitimate. It considers whether there are any facts otherwise unexplained, whether the proposed explanation will include all the facts known, and whether the supposition of the crime is the simplest explanation of the facts known of the accused. If the answer to each of these inquiries is affirmative, the Grand Jury reports "a true bill," or legitimate hypothesis.

The case being brought to trial, since all inductive proof proceeds from observation, witnesses are brought to testify to their own observations.

"Oral evidence must in all cases be direct; that is to say —

"If it refers to a fact alleged to have been seen, it must be the evidence of a witness who says he saw it;

"If it refers to a fact alleged to have been heard, it must be the evidence of a witness who says he heard it;

"If it refers to a fact alleged to have been perceived by any other sense or in any other manner, it must be the evidence of a witness who says he perceived it by that sense or in that manner;

"If it refers to an opinion or the grounds on which that opinion is held, it must be the evidence of the person who holds that opinion on those grounds."[1]

The grounds upon which testimony is accepted have been well set forth by David Hume in his famous essay "Of Miracles":—

"All effects follow not with like certainty from their supposed causes. Some events are found, in all countries and all ages, to have been constantly joined together: others are found to have been more variable, and sometimes to disappoint our expectations;

[1] Stephen's *Digest of the Law of Evidence* (Amer. ed.), p. 126.

so that in our reasonings concerning matters of fact, there are all imaginable degrees of assurance, from the highest certainty to the lowest species of moral evidence.

"A wise man, therefore, proportions his belief to the evidence. In such conclusions as are founded on an infallible experience, he expects the event with the last degree of assurance, and regards his past experience as full *proof* of the future existence of that event. In other cases he proceeds with more caution: he weighs the opposite experiments: he considers which side is supported by the greater number of experiments: to that side he inclines with doubt and hesitation; and when at last he fixes his judgment, the evidence exceeds not what we properly call *probability*. All probability then supposes an opposition of experiments and observations, where the one side is found to overbalance the other, and to produce a degree of evidence proportioned to the superiority. A hundred instances or experiments on one side, and fifty on another, afford a doubtful expectation of any event; though a hundred uniform experiments, with only one that is contradictory, reasonably beget a pretty strong degree of assurance. In all cases we must balance the opposite experiments, where they are opposite, and deduct the smaller number from the greater, in order to know the exact force of the superior evidence.

"To apply these principles to a particular instance; we may observe, that there is no species of reasoning more common, more useful, and even necessary to human life, than that which is derived from the testimony of men, and the reports of eye-witnesses and spectators. This species of reasoning, perhaps, one may deny to be founded on the relation of cause and effect. I shall not dispute about a word. It will be sufficient to observe, that our assurance in any argument of this kind is derived from no other principle than our observation of the veracity of human testimony, and of the usual conformity of facts to the report of witnesses. It being a general maxim that no objects have any discoverable connection together, and that all the inferences which we can draw from one to another, are founded merely on our experience of their constant and regular conjunction, it is evident that we ought not to make an exception to this maxim in favor of human testimony, whose connection with any event seems, in

itself, as little necessary as any other. Were not the memory tenacious to a certain degree; had not men commonly an inclination to truth and a principle of probity; were they not sensible to shame when detected in a falsehood: were not these, I say, discovered by *experience* to be qualities inherent in human nature, we should never repose the least confidence in human testimony. A man delirious, or noted for falsehood and villany, has no manner of authority with us.

"And as the evidence derived from witnesses and human testimony is founded on past experience, so it varies with the experience, and is regarded as a *proof* or a *probability*, according as the conjunction between any particular kind of report, and any kind of object, has been found to be constant or variable.

"The reason why we place any credit in witnesses and historians, is not derived from any *connection* which we perceive *a priori* between testimony and reality, but because we are accustomed to find a conformity between them. But when the fact attested is such a one as has seldom fallen under our observation, here is a contest of two opposite experiences, of which the one destroys the other as far as its force goes, and the superior can only operate on the mind by the force which remains.

"*I should not believe such a story were it told me by* CATO, was a proverbial saying in Rome, even during the lifetime of that philosophical patriot. The incredibility of a fact, it was allowed, might invalidate so great an authority."

It is clear, then, that the reason why testimony is received is that we have made the primary induction that the testimony of respectable men is usually conjoined with fact. It makes little difference whether this conjunction be regarded as a fact of coexistence or of causation.

When a man is charged with a crime, witnesses may testify directly that they perceived him commit it. Here the logical process is brief: Human testimony is true; These witnesses testify that they saw the act of

crime; Therefore the man is guilty. This is a secondary induction.

But more often we must proceed by a longer road. The witnesses cannot testify directly to the fact charged; they can testify only to other facts which are related to the fact charged. Such facts are said to be *relevant* to the fact in issue. The rules of Relevancy are simply the statements of the primary inductions which lawmakers have accepted as well established, regarding the connections of certain kinds of facts. Human testimony may be accepted as true; but if testimony is offered to a fact, the previous question must be raised whether we have any primary induction that the existence of the fact it is proposed to prove is usually connected with the existence or non-existence of the fact charged. In the famous Salem witchcraft cases, which left so dark a blot upon the early history of New England, the fallacy was that the relevancy of the facts proved to the crime charged had not been established by any induction. If the rulings of courts appear to exclude certain kinds of evidence, commonly accepted by private persons, it is because the primary induction has been made that the connection of those facts is uncertain, and because many persons are extremely careless in adopting unsubstantiated reports. There is nothing peculiar in the logic of courts, nor should a single principle be admitted, except such as judicious men apply in reaching their own private conclusions.

The following statements of the principles of relevancy are taken from Stephen's *Digest of the Law of Evidence*:—

"Evidence may be given, in any proceeding, of any fact in issue,

and of any fact relevant to any fact in issue unless it is hereinafter declared to be deemed irrelevant,

and of any fact hereinafter declared to be deemed relevant to the issue whether it is or is not relevant thereto."[1]

"Facts whether in issue or not, are relevant to each other when one is, or probably may be, or may have been—

the cause of the other;

the effect of the other;

an effect of the same cause;

a cause of the same effect:

or when the one shows that the other must or cannot have occurred, or probably does or did exist or not;

or that any fact does or did exist or not which in the common course of events would either have caused or been caused by the other;

provided that such facts do not fall within the exclusive rules contained in chapters iii, iv, v, vi; or that they do fall within the exceptions to those rules contained in those chapters."[2]

ILLUSTRATIONS.

"*(a)* A's death is caused by his taking poison. The administration of the poison is relevant to A's death as its cause. A's death is relevant to the pǒisoning as its effect.

"*(b)* A and B each eat from the same dish and each exhibit symptoms of the same poison. A's symptoms and B's symptoms are relevant to each other as effects of the same cause.

"*(c)* The question is, whether A died of the effects of a railway accident.

"Facts tending to show that his death was caused by inflammation of the membranes of the brain, which probably might be caused by the accident; and facts tending to show that his death was caused by typhoid fever, which have nothing to do with the accident, are relevant to each other as possible causes of tne same effect — A's death.

[1] Stephen's *Digest*, p. 5.

[2] *Ibid.*, p. 246.

"(*d*) A is charged with committing a crime in London on a given day. The fact that on that day he was at Calcutta is relevant as proving that he could not have committed the crime.

"(*e*) The question is, whether A committed a crime.

"The circumstances are such that it must have been committed either by A, B, or C. Every fact which shows this, and every fact which shows that neither B nor C committed it, or that either of them did or might have committed it, is relevant.

"(*f*) B, a person in possession of a large sum of money, is murdered and robbed. The question is, whether A murdered him. The fact that after the murder A was or was not possessed of a sum of money unaccounted for is relevant, as showing the existence or absence of a fact which, in the common course of events, would be caused by A's committing the murder. A's knowledge that B was in possession of the money would be relevant as a fact, which, in the ordinary course of events, might cause or be one of the causes of the murder.

"(*g*) A is murdered in his own house at night. The absence of marks of violence to the house is relevant to the question, whether the murder was committed by a servant, because it shows the absence of an effect which would have been caused by its being committed by a stranger."[1]

"Four classes of facts, which in common life would usually be regarded as falling within this definition of relevancy, are excluded from it by the Law of Evidence except in certain cases:

"1. Facts similar to, but not specifically connected with each other. (*Res inter alias actae.*)

"2. The fact that any person not called as a witness has asserted the existence of any fact. (Hearsay.)

"3. The fact that any person is of opinion that a fact exists. (Opinion.)

"4. The fact that a person's character is such as to render conduct imputed to him probable or improbable. (Character.)

"To each of these four exclusive rules there are, however, important exceptions, which are defined by the Law of Evidence."[2]

[1] Stephen's *Digest*, p. 247.
[2] *Ibid.*, p. xiii.

It is plain that the reason that "hearsay is not evidence" is that to accept hearsay is to violate the fundamental rule of inductive logic, which is, Make sure of your observations. All the other rules of exclusion are, in like manner, based upon scientific grounds. The whole progress of judicial science, in the trying of cases, is but an increase of precision in applying the principles of inductive logic.

CHAPTER XV.

FALLACIES.

We cannot open the subject of Fallacies in a more interesting way than by introducing Bacon's classic discussion of the "Idols" in his *Novum Organum:* —

XXXIX.

"There are four classes of Idols which beset men's minds. To these for distinction's sake I have assigned names, — calling the first class *Idols of the Tribe;* the second, *Idols of the Cave;* the third, *Idols of the Market-place;* the fourth, *Idols of the Theatre.*

XL.

"The formation of ideas and axioms by true induction is no doubt the proper remedy to be applied for the keeping off and clearing away of idols. To point them out, however, is of great use; for the doctrine of Idols is to the Interpretation of Nature what the doctrine of the refutation of Sophisms is to common Logic.

XLI.

"The Idols of the Tribe have their foundation in human nature itself, and in the tribe or race of men. For it is a false assertion that the sense of man is the measure of things. On the contrary, all perceptions as well of the sense as of the mind are according to the measure of the individual and not according to the measure of the universe. And the human understanding is like a false mirror, which, receiving rays irregularly, distorts and discolours the nature of things by mingling its own nature with it.

XLII.

"The Idols of the Cave are the idols of the individual man. For every one (besides the errors common to human nature in general) has a cave or den of his own, which refracts and discolours the light of nature; owing either to his own proper and peculiar nature; or to his education and conversation with others; or to the reading of books, and the authority of those whom he esteems and admires; or to the differences of impressions, accordingly as they take place in a mind preoccupied and predisposed or in a mind indifferent and settled; or the like. So that the spirit of man (according as it is meted out to different individuals) is in fact a thing variable and full of perturbation, and governed as it were by chance. Whence it was well observed by Heraclitus that men look for sciences in their own lesser worlds, and not in the greater or common world.

XLIII.

"There are also Idols formed by the intercourse and association of men with each other, which I call Idols of the Market-place, on account of the commerce and consort of men there. For it is by discourse that men associate; and words are imposed according to the apprehension of the vulgar. And therefore the ill and unfit choice of words wonderfully obstructs the understanding. Nor do the definitions or explanations wherewith in some things learned men are wont to guard and defend themselves, by any means set the matter right. But words plainly force and overrule the understanding, and throw all into confusion, and lead men away into numberless empty controversies and idle fancies.

XLIV.

"Lastly, there are Idols which have immigrated into men's minds from the various dogmas of philosophies, and also from wrong laws of demonstration. These I call Idols of the Theatre; because in my judgment all the received systems are but so many stage-plays, representing worlds of their own creation after an

unreal and scenic fashion. Nor is it only of the systems now in vogue, or only of the ancient sects and philosophies, that I speak; for many more plays of the same kind may yet be composed and in like artificial manner set forth; seeing that errors the most widely different have nevertheless causes for the most part alike. Neither again do I mean this only of entire systems, but also of many principles and axioms in science, which by tradition, credulity, and negligence have come to be received.

"But of these several kinds of Idols I must speak more largely and exactly, that the understanding may be duly cautioned.

XLV.

"The human understanding is of its own nature prone to suppose the existence of more order and regularity in the world than it finds. And though there be many things in nature which are singular and unmatched, yet it devises for them parallels and conjugates and relatives which do not exist. Hence the fiction that all celestial bodies move in perfect circles; spirals and dragons being (except in name) utterly rejected. Hence, too, the element of Fire with its orb is brought in, to make up the square with the other three which the sense perceives. Hence, also, the ratio of density of the so-called elements is arbitrarily fixed at ten to one. And so on of other dreams. And these fancies affect not dogmas only, but simple notions also.

XLVI.

"The human understanding when it has once adopted an opinion (either as being the received opinion or as being agreeable to itself) draws all things else to support and agree with it. And though there be a greater number and weight of instances to be found on the other side, yet these it either neglects and despises, or else by some distinction sets aside and rejects; in order that by this great and pernicious predetermination the authority of its former conclusions may remain inviolate. And, therefore, it was a good answer that was made by one who, when they showed him hanging in a temple a picture of those who had paid their vows as

having escaped shipwreck, and would have him say whether he did not now acknowledge the power of the gods, — 'Aye,' asked he again, 'but where are they painted that were drowned after their vows?' And such is the way of all superstition, whether in astrology, dreams, omens, divine judgments, or the like; wherein men, having a delight in such vanities, mark the events where they are fulfilled, but where they fail, though this happen much oftener, neglect and pass them by. But with far more subtlety does this mischief insinuate itself into philosophy and the sciences; in which the first conclusion colors and brings into conformity with itself all that come after, though far sounder and better. Besides, independently of that delight and vanity which I have described, it is the peculiar and perpetual error of the human intellect to be more moved and excited by affirmatives than by negatives; whereas it ought properly to hold itself indifferently disposed towards both alike. Indeed, in the establishment of any true axiom, the negative instance is the more forcible of the two.

XLVII.

"The human understanding is moved by those things most which strike and enter the mind simultaneously and suddenly, and so fill the imagination; and then it feigns and supposes all other things to be somehow, though it cannot see how, similar to those few things by which it is surrounded. But for that going to and fro to remote and heterogeneous instances, by which axioms are tried as in the fire, the intellect is altogether slow and unfit, unless it be forced thereto by severe laws and overruling authority.

XLIX.

"The human understanding is no dry light, but receives an infusion from the will and affections; whence proceed sciences which may be called 'sciences as one would.' For what a man had rather were true he more readily believes. Therefore he rejects difficult things from impatience of research; sober things, because they narrow hope; the deeper things of nature, from superstition; the light of experience, from arrogance and pride, lest his mind should seem to be occupied with things mean and

transitory ; things not commonly believed, out of deference to the opinion of the vulgar. Numberless, in short, are the ways, and sometimes imperceptible, in which the affections color and infect the understanding.

L.

"But by far the greatest hindrance and aberration of the human understanding proceeds from the dulness, incompetency, and deceptions of the senses ; in that things which strike the sense outweigh things which do not immediately strike it, though they be more important. Hence it is that speculation commonly ceases where sight ceases ; insomuch that of things invisible there is little or no observation. Hence all the working of the spirits inclosed in tangible bodies lies hid and unobserved of men. So, also, all the more subtle changes of form in the parts of coarser substances (which they commonly call alteration, though it is in truth local motion through exceedingly small spaces) is in like manner unobserved. And yet unless these two things just mentioned be searched out and brought to light, nothing great can be achieved in nature, as far as the production of works is concerned. So, again, the essential nature of our common air, and of all bodies less dense than air (which are very many), is almost unknown. For the sense by itself is a thing infirm and erring ; neither can instruments for enlarging or sharpening the senses do much ; but all the truer kind of interpretation of nature is effected by instances and experiments fit and apposite ; wherein the sense decides touching the experiment only, and the experiment touching the point in nature and the thing itself." [1]

Since Inductive Logic includes all the deductive processes, it is liable to all of the fallacies treated of in works upon that branch. The fallacies peculiar to inductive logic are those which concern Observation and the making of primary inductions.

I. *Non-observation, or Prejudice.* — All induction being based upon observation, any opinion about facts

[1] Bacon's *Works*, vol. viii, p. 76 sq.

which does not begin in that way must be groundless. The student of nature must not enter the field of investigation provided with broad generalizations; as, that the effect must resemble the cause; that whatever is inconceivable is false; that the distinctions in nature correspond to the received distinctions in language, etc. A student of the Holy Scriptures, for instance, is not at liberty (although assured of the divine origin of Christianity by personal experience of its power) to lay down the dictum that a revelation from the God of truth can be mixed with none of the scientific errors of the times in which it was given. Nor can a student of anthropology, impressed with the dignity of man, assert, without examination, that we are not descended from ape-like ancestors, with pointed ears and long tails.

But, since observation is laborious, and the mind is impatient for conclusions, all men are tempted to excuse themselves from the fatigue of examination and to taste at once the pleasure of feeling that they know.

The most eminent leaders of inductive science have not escaped this fallacy.

"Aristotle held some peculiar notions with respect to the skull. He says, 'that part of the head which is covered with hair is called the cranium; the fore part of this is called the sinciput; this is the last formed, being the last part in the body which becomes hard.' He correctly alludes here to the opening in the frontal bone of a young infant, which gradually becomes hardened by ossification; 'the hinder part is the occiput, and between the occiput and sinciput is the crown of the head; the brain is placed beneath the sinciput, and the occiput is empty (!). The skull has sutures; in women there is but one, placed in a circle (!); men have generally three joined in one, and a man's skull has been seen

without any sutures at all.' The often-repeated question as to how far Aristotle's observations are the result of his own investigation, naturally suggests itself again here; had Aristotle ever dissected a human body, he never would have asserted a proposition so manifestly false as that the back of the head is empty, or that women have only one suture placed in a circle." [1]

Another example can be taken from the *Novum Organum* itself:—

"Again, it has been observed that small wooden arrows without an iron point, discharged from large engines, pierce deeper into wooden material (say the sides of ships, or the like) than the same arrows tipped with iron, on account of the similarity of substance between the two pieces of wood; although this property had previously been latent in the wood." [2]

One variety of prejudice is the unquestioning acceptance of an opinion as to facts upon the *Authority* of some great man. In early life, all must receive many things upon the authority of parents and teachers. But the purpose of education is wholly to remove this dependence, so that the adult man shall know the grounds of his own beliefs. The Protestant Reformation was much more than merely a theological or religious movement; it was an intellectual revolt against authority. Advancing thought cannot leave any part of the field of facts outside the scrutiny of inductive science, not even the facts of religion; for in the domain of science there is no pope. But many Protestants still bow to authority, and those most independent of the authority of tradition often accept without ques-

[1] Quoted by Fowler from the *Quarterly Review* for January, 1865. *Inductive Logic*, p. 262.

[2] Page 226.

tion the dicta of the supposed prophets of advanced thought.

In the best schools of the present day, the teacher imposes no dogmas by virtue of his own authority; he claims no exhaustive and finished knowledge of his subject. Simply as an older investigator, he invites the pupil to inspect the results already reached, and to take a place beside his teacher at the boundary of knowledge, and push it further outwards. That teacher fails in his most important duty, who does not impress his students with the present incompleteness of his science, and the inadequacy of all the text-books in use. It was Agassiz's custom to give to the beginner a fish and require him to look at it for himself; so great a teacher never made the mistake of substituting his own books for the book of nature.

"But an undiscriminating submission to the authority of contemporaries, of which I have hitherto exclusively spoken, has been but a slight source of error when compared with undiscriminating submission to the authority of past generations. The latter involves a kind of compound fallacy. The authority of an Aristotle or a Galen has come, by the process already described, to be received without question and without limit by his own or by the succeeding generation; and then, by the constant repetition of a similar process, it is received from that generation by the leading minds of the next, from them by their contemporaries, and so on, respect for tradition being blended with respect for a great name, and both these resting for their support on the deference paid to established authority. Many of the propositions accepted without the slightest hesitation by previous generations on this kind of authority now appear to us patently absurd, nor is it without effort that we can realize the universality of their former reception." [1]

[1] Fowler's *Inductive Logic*, p. 292.

"Of this tendency we have many 'glaring instances,' as Bacon would call them. The error has been, so to say, canonized in the proverb '*Mallem cum Platone errare.*' There is a characteristic anecdote of Scheiner, who contests with Galileo the honor of having been the first to observe the spots on the sun. Scheiner was a monk; and, on communicating to the superior of his order the account of the spots, he received in reply from that learned father a solemn admonition against such heretical notions: 'I have searched through Aristotle,' he said, 'and can find nothing of the kind mentioned; be assured, therefore, it is a deception of your senses, or of your glasses.'"[1]

II. *Partial Observation, or the Neglect of Negative Instances.* — This is the most subtle and dangerous of all the fallacies, and the hardest to correct. Practically, the section which treats of this fallacy is the most important one in any text-book of inductive logic. As soon as a few similar phenomena are perceived, the mind moves naturally toward a primary induction. Having observed that this *A* and that *A* and the other *A* are *X*, the generalization is suggested that all *A*'s are *X*; sometimes, indeed, a *single* case is enough to beget an opinion. When this opinion has been a little while entertained, the minds of most persons seem almost wholly to lose the power to notice the cases in which an *A* is not *X*; every positive instance is observed, and confirms the conviction, but the negative instances are either entirely overlooked, or else lightly explained away.

The following case is taken from Brachet's *Historical Grammar of the French Tongue*: —

[1] Baden Powell's *History of Natural Philosophy*, p 171. Quoted in Fowler's *Inductive Logic*, p. 292

"The tendency to simplify and reduce the number of cases was early felt in the popular Latin; the cases expressed shades of thought too delicate and subtle for the coarse mind of the Barbarian. And so, being unable to handle the learned and complicated machinery of the Latin declensions, he constructed a system of his own, simplifying its springs, and reducing the number of the effects at the price of frequently reproducing the same form. Thus the Roman distinguished by means of case-terminations the place where one is, from the place to which one is going: 'veniunt ad domum,' 'sunt in domo.' But the Barbarian, unable to grasp these finer shades, saw no use in this distinction, and said, in either case alike, 'sum in domum,' 'venio ad domum.'

"Thus, from the fifth century downwards, long before the first written records of the French language, popular Latin reduced the number of cases to two: (1) The nominative to mark the subject; and (2) that case which occurred most frequently in conversation, the accusative, to mark the object or relation. From that time onwards the Latin declension was reduced to this:—subject, *murus;* object, *murum.*

"The French language is the product of the slow development of popular Latin; and French grammar, which was originally nothing but a continuation of the Latin grammar, inherited, and in fact possessed from its infancy, a completely regular declension; subject, *murs, murus;* object, *mur, murum;* and people said, 'ce *murs* est haut'; 'j'ai construit un *mur.*'

"This declension in two cases forms the exact difference between ancient and modern French. It disappeared in the fourteenth century, not without leaving many traces in the language, which look like so many insoluble exceptions, but find their explanation and historic justification in our knowledge of the Old French declension."[1]

Here it will be observed that the single instance of change from the full declension of nouns in Latin to

[1] Dr. Kitchin's Trans., p. 88. Seventh Edition, pp. 98–100, mistakenly quoted by Dr. Fowler (*Inductive Logic*, p. 201) as an illustration of concomitant variations.

the non-inflection of nouns in French has suggested to M. Brachet the generalization that barbarians cannot readily understand and handle declensions. This is, of course, in the face of the negative facts that these same barbarians spoke the inflected Teutonic languages, that fully inflected languages are found among barbarians in Africa, in Arabia, and in all parts of the earth; indeed, that the history of the most cultivated languages has been to pass from full inflection in barbarous times to less inflection in days of civilization. He who would hear the most delicate inflections of the Arabic, used with precision, must go among the illiterate sons of the desert, not into the cities. Yet very few of the readers of M. Brachet's most interesting work ever think of these negative instances. There is, to most persons, something distasteful in assuming a critical attitude toward an author; ingenious and pleasing generalizations find with ordinary readers unchallenged acceptance.

This fallacy is peculiarly safe from detection when, in a generalization, we have mistakenly put species for genus. For example, it was believed by many grammarians of the last generation that the Greek Aorist tense, which almost exactly corresponds in meaning to the English preterite, "denotes a single or momentary action." Instances in which single or momentary actions were expressed in the aorist were common enough. The fallacy was exactly like that of assuming that all Americans are Virginians, or more precisely, that the name Americans belongs most naturally and properly to Virginians, because Virginians are Americans. Such cases as "These all died," where the verb

is aorist, were explained as viewing a single instance as representative; cases like "He abode two whole years in his own hired dwelling" were overlooked. Eminent theologians went so far as to base the proof of the doctrine that "we all sinned in Adam" on the fact that St. Paul uses the aorist in saying "all sinned"; and since that must "denote a single and momentary action" of the whole race, it could, of course, be nothing else than eating the forbidden fruit in the garden of Eden.

A very common definition of a verb in the grammars of our public schools is, "A verb is a word which expresses action, being, or state." Hundreds of teachers have taught this definition to their pupils without noticing that the three words "action," "being," and "state" in the definition are all *negative instances;* they express action, being, and state, and yet are *not* verbs. Such nouns as love, hate, murder, theft, peace, existence, etc., appear on every page, and yet it never occurs to these teachers that, according to their definition, these words should be verbs. The fallacy is in taking that for a mark of a species which is the mark of the genus in which the species is included, and which the species in question shares with others.

"We would strongly recommend to any of our readers whose occupations lead them to attend to the 'signs of the weather,' and who, from hearing a particular adage often repeated, and from noticing themselves a few remarkable instances of its verification, have 'begun to put faith in it,' to commence keeping a note-book, and to set down without bias all the instances which occur to them of the recognized antecedent, and the occurrence or non-occurrence of the expected consequent, not omitting, also, to set down the cases in which it is left undecided; and, after so collecting a

number of instances (not less than a hundred), to proceed to form his judgment on a fair comparison of the favorable, the unfavorable, and the undecided cases; remembering always that the *absence of a majority one way would be in itself an improbability*, and that, therefore, to have any weight, the majority should be a very decided one, and *that* not only in itself, but in reference to the neutral instances. We are all involuntarily much more strongly impressed by the fulfilment than by the failure of a prediction, and it is only, when thus placing ourselves face to face with fact and experience, that we can fully divest ourselves of this bias."[1]

III. *Malobservation.* — It is possible to make careful observations, but to misunderstand what we observe. The simple sensations which the brain receives are interpreted in accordance with primary inductions more or less inexact. The far greater part of all our so-called observations are necessarily inferences, and we are often most in error when acting upon what seems the direct evidence of our own senses. Here is an example from the *Novum Organum*: —

"On this subject, therefore, we may take the following as an Instance of the Fingerpost. We see in large fires how high the flames ascend; for the broader the base of the flame, the higher is its vertex. Thus extinction appears to commence at the sides, where the flame is compressed and troubled by the air. But the heart of the flame, which is not touched by the air but surrounded by other flame on all sides, remains numerically identical; nor is it extinguished until gradually compressed by the surrounding air. Thus all flame is in the form of a pyramid, being broader at the base where the fuel is, but sharp at the vertex, where the air is antagonistic and fuel is wanting. But smoke is narrow at the base, and grows broader as it ascends, like an inverted pyramid; the reason being that the air admits smoke and compresses flame.

[1] Sir John Herschel's *Familiar Lectures on Scientific Subjects*, Lecture IV, quoted by Fowler, *Inductive Logic*, p. 257.

For let no one dream that lighted flame is air, when in fact they are substances quite heterogeneous."[1]

Bacon in this instance did not really see what he thought he saw. Other illustrations have been already given in the chapter on Observation (page 9).

IV. *Mistake in Area.* — A primary induction may be correct, but we may mistake its area. It is important to know whether the instances examined have come at random from all parts of the field regarding which we generalize. Before deciding that all lobsters are red, the inquirer must be sure that all his observations have not been confined to boiled specimens. Often it is possible to be sure of an induction over a certain area, while it is held as only provisionally true over a broader field. Here comes in the principle which justifies the applying of inductions to what are called "*adjacent cases*." Since at any moment it is unlikely that we have reached the boundary of our territory, there are probably at least a few more cases of the same sort between us and that boundary. If we find ourselves upon a line of uniformity, it is improbable that we have struck it just at the end. A traveler from Liverpool to London, having for fifty miles observed red poppies growing in the grain fields, will expect to see *some* more red poppies; but he will not have so positive an expectation of seeing them all the way to the capital.

Hume says: —

"The Indian prince, who refused to believe the first relations concerning the effects of frost, reasoned justly; and it naturally required a very strong testimony to engage his assent to facts that

arose from a state of nature with which he was unacquainted, and which bore so little analogy to those events of which he had constant and uniform experience. Though they were not contrary to his experience, they were not conformable to it."

The Indian prince simply made a mistake as to the area regarding which his observations qualified him to affirm; and that is precisely the mistake of Hume himself, in his famous argument against miracles.

The ancients made this error in studying the laws of motion. Mr. Mill says: —

"This assertion [that all bodies in motion continue to move in a straight line with uniform velocity until acted upon by some new force] is in open opposition to first appearances; all terrestrial objects, when in motion, gradually abate their velocity, and at last stop; which, accordingly, the ancients, with their *inductio per enumerationem simplicem*, imagined to be the law."[1]

The induction which the ancients made was correct, and was made in the only possible way; they only mistook its area. What they established was the universal truth under ordinary conditions; their error was in supposing that the truth held under all conditions.

V. *Mistake in Isolation.* — The rules for isolating facts of causation seem so simple, their application seems so easy, and their results seem so sure, that we are likely to forget how much their value is diminished by the difficulty of ascertaining whether we have taken account of all relevant circumstances. Dr. Fowler says: —

"A bullet is fired from a gun, or a dose of prussic acid is administered, and an animal instantly falls down dead. There is

[1] *Logic*, p. 290.

no hesitation in ascribing the death to the gun-shot wound or the dose of poison. Nor is this confidence the effect of any wide experience, for if it were the first time that we had seen a gun fired, or a dose of poison administered, we should have no hesitation in ascribing the altered condition of the animal to this novel cause; we should know that there was only one new circumstance operating upon it, and consequently, that any change in its condition must be due to that one circumstance."[1]

This analysis is wholly incorrect. When a man falls dead on the street we are at a loss for a cause. Many events, observable and unobservable, are occurring at the same time; the man may have had heart disease. We proceed to make an hypothesis according to the established rules. The first inquiry of the mind is for some already accepted primary induction under which to class the event. If a small boy should shoot off a Chinese fire-cracker, and at that moment some one should fall, we should not connect the two events, because we already have the induction that fire-crackers do not kill.

This impossibility of knowing always whether isolation is perfect, leads to the rule that in studying any phenomenon, we should *vary the circumstances* as much as possible, and use each of the applicable methods of proof independently. Yet even then we are liable to err, as the following example shows:—

"Thales of Miletus, who lived in the sixth century B.C., and who was called 'the first of natural philosophers' by Tertullian, and 'the first who inquired after natural causes' by Lactantius, affirmed that water was the first principle of things, perhaps, according to some writers, because Homer had made Okeanos the source of the gods. At least we are reminded of the boundless

[1] *Inductive Logic*, p. 151.

watery chaos of older cosmogonies. This doctrine of Thales was not without its supporters during the Middle Ages, and, indeed, the convertibility of water into earth and air was not absolutely disproved until about a century ago. One of the ablest supporters of the dogma was Van Helmont (b. 1577, d. 1644), who affirmed that all metals, and even rocks, may be resolved into water ; animal substances are produced from it, because fish live upon it ; and vegetable substances may also be produced from it. This assertion he endeavored to prove by what would appear to be a very conclusive experiment in those days, when neither the composition of the air nor of water was known. He took a willow which weighed five pounds, and planted it in two hundred pounds of earth, which he had previously carefully dried in an oven. The willow was frequently watered, and at the end of five years he pulled it up and found that its weight amounted to one hundred and sixty-nine pounds and three ounces. The earth was again dried and was found to have lost only two ounces. Thus it appeared that 164 pounds of wood, bark, roots, leaves, etc., had been produced from water alone. Hence he inferred that all vegetables are produced from water alone ; not knowing, as was afterwards proved by Priestley, that a constituent of the atmosphere, called carbonic acid, had furnished the solid part of the tree, although, indeed, there was much water with it."[1]

This experiment of Van Helmont was, so far as he could know, a rigorous application of the famous test of difference ; yet it wholly failed to teach the truth, because the supposed isolation was unreal.

Under this head belongs the well-known fallacy *Post hoc, ergo propter hoc.* No one would have the hardihood to argue that since the group of antecedents *ABCDEFGHIJK* have been followed by the consequents *lmnopqrstuv*, therefore *C* must be the cause of *q* ; but it is often convenient for a crank or a demagogue to fasten attention upon the fact that after *C*

[1] Rodwell's *Birth of Chemistry*, p. 14.

followed q, the unspoken assumption being that isolation is conceded, that C was the *only* new antecedent, and q the *only* new consequent. Thus, it is a familiar fact in politics that hard times, whatever may have been their causes, discredit the party in power, the outs arguing that since the present administration came into office money has been scarce, and wholly omitting to refer to speculation, drought, or any other cause of financial depression.

It is a mistake in isolation to overlook the *Mutuality of Cause and Effect*. This is illustrated in the following remarks of Sir G. C. Lewis:—

"An additional source of error in determining political causation is likewise to be found in the *mutuality of cause and effect*. It happens sometimes that when a relation of causation is established between two facts it is hard to decide which, in the given case, is the cause and which the effect, because they act and react upon each other, each phenomenon being in turn cause and effect. Thus, habits of industry may produce wealth; while the acquisition of wealth may promote industry; again, habits of study may sharpen the understanding, and the increased acuteness of the understanding may afterward increase the appetite for study. So the excess of population may, by impoverishing the laboring classes, be the cause of their living in bad dwellings; and, again, bad dwellings, by deteriorating the moral habits of the poor, may stimulate population. The general intelligence and good sense of the people may promote its good government, and the goodness of the government may in its turn increase the intelligence of the people, and contribute to the formation of sound opinions among them. Drunkenness is in general the consequence of a low degree of intelligence, as may be observed both among savages and in civilized countries. But, in return, a habit of drunkenness prevents the cultivation of the intellect, and strengthens the cause out of which it grows. As Plato remarks, education improves nature, and nature facilitates education. National character, again, is

both effect and cause; it reacts on the circumstances from which it arises. The national peculiarities of a people, its race, physical structures, climate, territories, etc., form originally a certain character, which tends to create certain institutions, political and domestic, in harmony with that character. These institutions strengthen, perpetuate, and reproduce the character out of which they grew, and so on in succession, each new effect becoming, in its turn, a new cause. Thus a brave, energetic, restless nation, exposed to attack from neighbors, organizes military institutions: these institutions promote and maintain a warlike spirit; this warlike spirit, again, assists the development of the military organization, and it is further promoted by territorial conquests and success in war, which may be its result — each successive effect thus adding to the cause out of which it sprung."[1]

[1] *On Methods of Observation and Reasoning in Politics*, vol. i, p. 375, quoted by Fowler, *Inductive Logic*, p. 322.

CHAPTER XVI.

THE WORK OF BACON.

Two great names stand out conspicuous beyond all others in the development of Inductive Logic: they are those of Bacon and of Mill. Of the latter enough has already been said to give the reader a knowledge of the main points of his doctrine. The last chapter contains a long quotation which well represents the style of the *Novum Organum*. But it seems undesirable to close this book without devoting a brief chapter to an estimate of the debt which we owe to that "Prince of Philosophers," who, with the "Prince of Poets," according to Lord Macaulay, "made the Elizabethan age a more glorious and important era in the history of the human mind than the age of Pericles, of Augustus, or of Leo."

Francis Bacon, Baron Verulam (1561–1626), is commonly regarded as the founder of modern inductive science. Reid expresses this opinion as follows: —

> "After man had labored in the search of truth near two thousand years by the help of Syllogisms, Lord Bacon proposed the method of INDUCTION as a more effectual engine for that purpose. His *Novum Organum* gave a new turn to the thoughts and labors of the inquisitive, more remarkable and more useful than that which the *Organon* of Aristotle had given before, and may be considered a second grand era in the progress of human nature." [1]

[1] Hamilton's *Reid*, p. 712; quoted by Minto, *Logic*, p. 244.

This is Bacon's own claim; he says:—

"All those who before me have applied themselves to the invention of arts have but cast a glance or two upon facts and examples and experience, and straightway proceeded, as if invention were nothing more than an exercise of thought, to invoke their own spirits to give them oracles. I, on the contrary, dwelling purely and constantly among the facts of nature, withdraw my intellect from them no further than may suffice to let the images and rays of natural objects meet in a point, as they do in the sense of vision; whence it follows that the strength and excellency of the wit has but little to do in the matter. And the same humility which I use in inventing I employ likewise in teaching. For I do not endeavor either by triumphs of confutation, or pleadings of antiquity, or assumption of authority, or even by the veil of obscurity, to invest these inventions of mine with any majesty; which might easily be done by one who sought to give lustre to his own name rather than light to other men's minds. I have not sought (I say), nor do I seek either to force or ensnare men's judgments, but I lead them to things themselves and the concordances of things, that they may see for themselves what they have, what they can dispute, what they can add and contribute to the common stock. And for myself, if in anything I have been either too credulous, or too little awake and attentive, or if I have fallen off by the way and left the inquiry incomplete, nevertheless I so present these things naked and open, that my errors can be marked and set aside before the mass of knowledge be further infected by them; and it will be easy, also, for others to continue and carry on my labors. And by these means I suppose that I have established forever a true and lawful marriage between the empirical and rational faculty, the unkind and ill-starred divorce and separation of which has thrown into confusion all the affairs of the common family."[1]

The claim of Bacon to be the very first cannot be allowed, but he remains the great prophet and leader of inductive investigation.

[1] Preface to the *Novum Organum.*

The truth is thus stated by Minto:—

"Undoubtedly Bacon's powerful eloquence and high political position contributed much to make the study of Nature fashionable. He was high in place and great in intellect, one of the commanding personalities of his time. Taking 'all knowledge for his province,' though study was really but his recreation, he sketched out a plan of universal conquest with a clearness and confidence that made the mob eager to range themselves under his leadership. He was the magnificent demagogue of science. There had been champions of 'Induction' before him, but they had been comparatively obscure and tongue-tied.

"While, however, we admit to the full the great services of this mighty advocate in making an 'Inductive' method popular, we should not forget that he had pioneers even in hortatory leadership. His happiest watchword, the Interpretation of Nature, as distinguished from the Interpretation of Authoritative Books, was not his invention. If we read Whewell's *History of the Inductive Sciences*, we shall find that many before him had aspired to 'give a new turn to the labors of the inquisitive,' and in particular to substitute inquisition for disquisition.

"One might compile from Whewell a long catalogue of eminent men before Bacon who held that the study of Nature was the proper work of the inquisitive: Leonardo da Vinci (1452–1519), one of the wonders of mankind for versatility, a miracle of excellence in many things, painter, sculptor, engineer, architect, astronomer, and physicist; Copernicus (1473–1543), the author of the Heliocentric theory; Telesius (1508–1588), a theoretical reformer, whose *De Rerum Natura* (1565) anticipated not a little of the *Novum Organum*; Cesalpinus (1520–1603), the Botanist; Gilbert (1540–1603), the investigator of Magnetism. By all these men experiment and observation were advocated as the only way of really increasing knowledge. They all derided mere book-learning. The conception of the world of sense as the original MS. of which systems of philosophy are but copies, was a familiar image with them."[1]

[1] Minto's *Logic, Inductive and Deductive*, pp. 245, 246.

Mr. Mill has made the following judicious criticism upon the work of Bacon:—

"It has excited the surprise of philosophers that the detailed system of inductive logic, which this extraordinary man labored to construct, has been turned to so little direct use by subsequent inquirers, having neither continued, except in a few of its generalities, to be recognized as a theory, nor having conducted in practice to any great scientific results. But this, though not unfrequently remarked, has scarcely received any plausible explanation; and some, indeed, have preferred to assert that all rules of induction are useless, rather than suppose that Bacon's rules are grounded upon an insufficient analysis of the inductive process. Such, however, will be seen to be the fact, as soon as it is considered, that Bacon entirely overlooked Plurality of Causes. All his rules imply the assumption, so contrary to all we now know of nature, that a phenomenon cannot have more than one cause.

"When Bacon is inquiring into what he terms the *forma calidi aut frigidi*, *gravis aut levis*, *sicci aut humidi*, and the like, he never for an instant doubts that there is some one thing, some invariable condition, or set of conditions, which is present in all cases of heat, or of cold, or of whatever other phenomenon he is considering; the only difficulty being to find what it is; which, accordingly, he tries to do by a process of elimination, rejecting or excluding, by negative instances, whatever is not the *forma* or cause, in order to arrive at what is. But, that this *forma* or cause is *one* thing, and that it is the same in all hot objects, he has no more doubt of than another person has that there is always some cause *or other*. In the present state of knowledge it could not be necessary, even if we had not already treated so fully of the question, to point out how widely this supposition is at variance with the truth. It is particularly unfortunate for Bacon that, falling into this error, he should have fixed almost exclusively upon a class of inquiries in which it was especially fatal, namely, inquiries into the causes of the sensible qualities of objects. For his assumption, groundless in every case, is false in a peculiar degree with respect to those sensible qualities. In regard to scarcely any of them has it been found possible to trace any unity

of cause, any set of conditions invariably accompanying the quality. The conjunctions of such qualities with one another constitute the variety of Kinds, in which, as already remarked, it has not been found possible to trace any law. Bacon was seeking for what did not exist. The phenomenon of which he sought for the one cause has oftenest no cause at all, and when it has, depends (as far as hitherto ascertained) upon an unassignable variety of distinct causes."[1]

[1] *Logic*, p. 532.

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